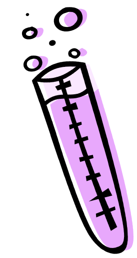
Acids and Bases Lesson 1



General Info about Acids and Bases

Acids:

- React with bases
- Taste ________________________ (don't taste in chemistry)
- React with certain active metals to produce ________________________
- Turn litmus paper ________________________

Bases:

- Reacts with acids
- ________________________ taste
- Feel ________________________
- Turn litmus paper ________________________

Arrhenius Theory

Acids vs Bases

- All acids produce ________________________ ions when they are dissolved in water. These ions are responsible for the acidic properties of these solutions.
- All bases produce ________________________ ions when they are dissolved in water. These ions are responsible for the basic properties of these solutions.

DO NOT COPY

General Idea

- The acidic properties of aqueous solutions of HCl (hydrochloric acid) and HNO_3(nitric acid) must be due to the hydrogen ions since they are the only ions ________________________ to both solutions.

The Arrhenius Model of Neutralization

- When equal molar quantities of an acid and a base are mixed in water, a solution is obtained that does not act as an acid or a base; it is ________________________ in terms of its acid-base properties. This kind of chemical reaction is a ________________________ reaction.

ACID + BASE $\longrightarrow$ SALT + WATER

Ex. Write the net ionic equation for the reaction below:

$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow$

Problems with Arrhenius' Theory

- **The Solvent Problem:** The nature of the solvent is very important in determining the acidic behaviour of a substance.
  - HCl is a strong acid and when it dissolves in water it ________________________ electricity well because there are lots of H^+ and Cl^- ions, however when HCl dissolves

in toluene it ________________________ conduct electricity which means there are few ions present. If there are few H+ ions present it would no longer be a strong acid.

- **The Salt Problem:** Salts solutions should not change the colour of litmus paper if they do not contain H+ ions or OH- ions because they would not be acids or bases (should be neutral).

Salt	Effect on Litmus	Conclusion
$NaCl$		
Na_3PO_4		
Na_2CO_3		
$NaNO_3$		
NH_4Cl		
$Pb(NO_3)_2$		

**How can* $Pb(NO_3)_2$ *be an acid if it needs to produce* H^+ *ions and how can* Na_2CO_3 *be a base if it needs to produce* OH^- *ions?*

The Brønsted-Lowry Theory

Acids vs Bases

- An acid is a molecule or ion that can ________________________a hydrogen ion. Any ion containing H atoms is a potential acid.
- A base is any molecule or ion that can react with (________________________) a hydrogen ion. Any ion with a pair of valence electrons available for bonding is a potential base.

DO NOT COPY

General Idea

- An acid is a hydrogen-ion ________________________, and a base is a hydrogen-ion ________________________.
- An acid can only act as an acid if a base is present and is willing/able to accept a hydrogen ion.
- This theory was able to explain the role of the solvent as well as the existence of acidic and basic salt solutions.

Dissociation of Brønsted-Lowry Acids

- Acids donate a proton (H^+) which combines with water to form ________________________ (H_3O^+). Often H^+ is used for convenience but the meaning is H_3O^+.

  Ex. $HCl_{(g)} + H_2O_{(l)} \longrightarrow$

- Water functions as a hydrogen-ion acceptor, or ________________________, in this reaction.
- H_3O^+ is an acid itself and can release an H^+ ion if the right ________________________ is present.

  Ex. $H_3O^+_{(aq)} + H_2O_{(l)} \rightleftharpoons H_2O_{(l)} + H_3O^+_{(aq)}$

Dissociation of Brønsted-Lowry Bases

- Metal hydroxides dissolve in water and produces ________________________directly which can accept an H^+ ion.

  Ex. $NaOH_{(s)} \xrightarrow[\text{in water}]{\text{dissolve}} Na^+_{(aq)} + OH^-_{(aq)}$

  $Ba(OH)_{2(s)} \xrightarrow[\text{in water}]{\text{dissolve}} Ba^{2+}_{(aq)} + 2\ OH^-_{(aq)}$

- There are bases that do not contain OH^- ions. With these bases H_2O can act as an acid by ________________________ a hydrogen ion and leaving an OH^- ready to react.

  Ex. $NH_{3(g)} + H_2O_{(l)} \longrightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

Example: Liquid hydrogen perchlorate, $HClO_4$, dissolves in water to form a solution of perchloric acid. Identify the hydrogen ion donor and acceptor, and write an equation for the solution process.

Example: A solution of gaseous methylamine, CH_3NH_2, turns red litmus blue. Write the balanced equation.

DO NOT COPY

Lewis Acids and Bases

- A more general definition than given by Brønsted and Lowry, it speaks to predicting acidity and basicity for substances like ammonia, NH_3
- **A Lewis base is an __________________________ donor.**
- **A Lewis acid is an __________________________ acceptor.**
- Lewis acids and bases are best described using **Lewis diagrams;** for instance:

$$\mathbf{H^{1+} \quad + \quad NH_3 \quad \rightarrow \quad NH_4^{1+}}$$

The hydrogen ion has no valence electrons. It is looking to acquire valence electrons through a **coordinate covalent bond**. It associates itself with the lone pair of electrons of the nitrogen. In this bond the nitrogen donates the electron pair to the hydrogen, which is the electron pair acceptor. The hydrogen is the Lewis acid and the ammonia is the Lewis base.

Another example involves boron trifluoride and ammonia:

$$BF_3 \quad + \quad NH_3 \quad \rightarrow \quad BF_3NH_3$$

A third example involves sulfur trioxide and water, to produce sulfuric acid:

$$SO_3 \quad + \quad H_2O \quad \rightarrow \quad H_2SO_4$$

Weak and Strong Acids and Bases

- The strongest acid that can exist in water is the ________________________ ion. The strongest base that can exist in water is the ________________________ ion.
- To differentiate acids that ionize completely from those that do not, we use the terms strong and weak. A ________________________ is completely ionized in solution. A ________________________is only partially ionized in solution. Hydrochloric acid is a strong acid even when it is dilute. Acetic acid is a weak acid even when it is concentrated.
- Bases can also be weak or strong. Sodium hydroxide is an example of a ________________________. It completely dissociates in water. Ammonia, however, is a ________________________.
- Strong acids and bases have ________________________ K values (because the products are favoured) and weak acids and bases have ________________________ K values because they do not produce a lot of ions (reactants are favoured).
- Since strong acids and bases have lots of ions in solution (favour products) they conduct electricity ________________________.
- Using a table of acid-dissociation constants is the surest way to quantify relative strengths of weak acids, but you can often classify acids and bases qualitatively as strong or weak just from their formulas:
  - **Strong acids**. Two types of strong acids, that you should memorize are:
    1. The ________________________ acids HCl, HBr, and HI
    2. Oxoacids in which the number of O atoms exceeds the number of ionizable protons by ______ or more, such as HNO_3, H_2SO_4, $HClO_4$; for example, in H_2SO_4, 4 O's – 2 H's =___
  - **Weak acids**. There are many more weak acids than strong ones. Four types are:
    1. The ________________________ acid HF
    2. Acids in which H is ________________________ to O or to a halogen, such as HCN and H_2S
    3. Oxoacids in which the number of O atoms equals or exceeds by ________________________ the number of ionizable protons, such as HClO, HNO_2, and H_3PO_4
    4. ________________________ acids (general formula RCOOH, with the ionizable proton shown in italics), such as CH_3COOH and C_6H_5COOH

DO NOT COPY

- **Strong bases**. Water-soluble compounds containing ________________________ ions are strong bases. The cations are usually those of the most active metals:
    1. M_2O or MOH, where M = ________________________ (1) metal (Li, Na, K, Rb, Cs)
    2. MO or $M(OH)_2$, where M = ________________________ (2) metal (Ca, Sr, Ba)
- **Weak bases**. Many compounds with an electron-rich ________________________ atom are weak bases. The common structural feature is an N atom with a lone pair (shown here in italics in the formulas):
    1. Ammonia (H_3)
    2. Amines (general formula RNH_2, R_2NH, or R_3N), such as $CH_3CH_2NH_2$, $(CH_3)_2NH$, and $(C_3H_7)_3N$

TABLE 15.1 Relative Strengths of Conjugate Acid–Base Pairs

	Acid, HA		Base, A^-		
Stronger acid	$HClO_4$ HCl H_2SO_4 HNO_3	Strong acids. 100% dissociated in aqueous solution.	ClO_4^- Cl^- HSO_4^- NO_3^-	Very weak bases. Negligible tendency to be protonated in aqueous solution.	Weaker base
	H_3O^+		H_2O		
	HSO_4^- H_3PO_4 HNO_2 HF CH_3CO_2H H_2CO_3 H_2S NH_4^+ HCN HCO_3^-	Weak acids. Exist in solution as a mixture of HA, A^-, and H_3O^+.	SO_4^{2-} $H_2PO_4^-$ NO_2^- F^- $CH_3CO_2^-$ HCO_3^- HS^- NH_3 CN^- CO_3^{2-}	Weak bases. Moderate tendency to be protonated in aqueous solution.	
	H_2O		OH^-		
Weaker acid	NH_3 OH^- H_2	Very weak acids Negligible tendency to dissociate.	NH_2^- O^{2-} H^-	Strong bases. 100% protonated in aqueous solution.	Stronger base

Examples H_2SeO_4

$(CH_3)_2CHCOOH$

KOH

$(CH_3)_2CHNH_2$

Acids and bases can be described using the terms strong, weak, dilute and concentrated. Which statement below is a correct use of the terms?

A. A strong acid cannot be dilute.
B. A weak acid cannot be concentrated.
C. The strength of acids varies during changes in concentration.
D. The strength of acids remains constant during changes in concentration.

Salts of Weak Acids and Bases

Ions of Neutral Salts			
Cations			
Na^{+}	K^{+}	Rb^{+}	Cs^{+}
Mg^{2+}	Ca^{2+}	Sr^{2+}	Ba^{2+}
Anions			
Cl^{-}	Br^{-}	I^{-}	
ClO_4^{-}	BrO_4^{-}	ClO_3^{-}	NO_3^{-}

Acidic Ions			
NH_4^{+}	Al^{3+}	Pb^{2+}	Sn^{2+}
HSO_4^{-}	$H_2PO_4^{-}$	HSO_3^{-}	

Basic Ions			
F^{-}	$C_2H_3O_2^{-}$	NO_2^{-}	HCO_3^{-}
CN^{-}	CO_3^{2-}	S^{2-}	SO_4^{2-}
HPO_4^{2-}	PO_4^{3-}		

DO NOT COPY

Example: Using an equation, show why a sodium nitrite solution is basic.

The sodium ions are ______________________________, but the basic nitrite ions will react with water

The formation of some ____ will render the solution ________________________.

Example: Account for the fact that sodium hydrogen carbonate produces a basic solution when it is dissolved in water.

The sodium ions are ______________________________, but the ______________________________ hydrogen carbonate ions will react with ______________________________:

The formation of some ____will render the solution ______________________________.

Example: Account for the fact that sodium hydrogen sulfite produces an acidic solution when it is dissolved in water.

Example: Account for the fact that salts containing ammonium produce acidic solutions when they are dissolved in water.

Ammonium reacts with water (which acts as a base, accepting a hydrogen ion).

Amphoteric Substances

- We`ve learned that water can act as an acid or a base:
  - $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ ← here water acts as a(n) ________________________.
  - $HCl + H_2O \rightarrow H_3O^+ + Cl^-$ ← here water acts as a(n) ________________________.
- Substances that can act as an acid in one reaction and a base in another are called __________________________or __________________________ substances.
- Another amphoteric substance is HSO_4^- (bisulphate ion).

DO NOT COPY

Polyprotic Acids

- Acids that can give up more than one hydrogen ion per molecule are called __________________________acids. Diprotic acids, which can release __________________________ hydrogen ions, are much more common than triprotic acids, which can release __________________________ hydrogen ions.

  Ex. Ionization of sulfuric acid:

  $$H_2SO_{4(aq)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + HSO_4^-{}_{(aq)}$$

  $$HSO_4^-{}_{(aq)} + H_2O_{(l)} \longleftrightarrow H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

  Ex. Ionization of Phosphoric acid

  $$H_3PO_{4(aq)} + H_2O_{(l)} \longleftrightarrow$$

Example: Write equations for the ionization of sulfurous acid in water.

See Acids and Bases Assignment

Name:____________________________________

Acids and Bases

1. Identify the hydrogen donor and acceptor in each of the following reactions:

$a)\ HNO_{3(l)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + NO_3^-{}_{(aq)}$

$b)\ C_2H_5NH_{2(l)} + H_2O_{(l)} \longrightarrow C_2H_5NH_3^+{}_{(aq)} + OH^-{}_{(aq)}$

$c)\ CH_3CO_2H_{(l)} + H_2O_{(l)} \longrightarrow CH_3CO_2^-{}_{(aq)} + H_3O^+_{(aq)}$

2. Which of the following would you expect to act as Brønsted-Lowry bases:

$a)\ Br^-$	$c)\ H_3PO_4$	$e)\ H_2O$
$b)\ Li^+$	$d)\ NH_4^+$	$f)\ NH_2^-$

3. Write the overall neutralization reaction equation and the net ionic equation for the reaction in aqueous solution between the following acids and bases:

DO NOT COPY

a) sulfuric acid and sodium hydroxide

b) hydrochloric acid and calcium hydroxide

4. A light bulb conductivity test was carried out on 1.0 M solutions of various bases. The bulb glowed brightly for potassium hydroxide, barium hydroxide, and lithium hydroxide solutions, but gave only weak flickers for methylamine and caffeine solutions. From this information determine which of these bases are strong and which are weak.

5. For each of the following, which one is the stronger acid:

   a) HNO_2 or HNO_3

   b) HIO_2 or HIO

   c) H_3AsO_4 or H_3AsO_3

6. Which compound in each group is the stronger acid in aqueous solution:

   a) H_2SO_3 or H_2SO_4

   b) $HBrO_2$ or $HBrO_3$

   c) H_3PO_4 or H_3PO_3

7. Which compound in each of the following pairs is the stronger acid:

a) H_2O or H_2S

b) H_2O or NH_3

8. Write the Brønsted-Lowry equations for the reactions with water of the following acids and bases, assuming that only one hydrogen ion is exchanged.

a) fluorosulfonic acid, FSO_3H, strong acid

b) sulfurous acid, H_2SO_3, weak acid

c) hydrogen bromide, *HBr*, a strong acid

d) perchloric acid, $HClO_4$, a strong acid

DO NOT COPY

e) hydrogen cyanide, *HCN*, a weak acid

f) hydrogen sulfide, H_2S, a weak acid

g) formic acid, HCO_2H, a weak acid

9. Write the reaction equations for the dissociation of each of the following substances in water and explain, with the use of Brønsted-Lowry reaction equations, the acidity or basicity of the resulting solutions:

a) potassium bisulfate, $KHSO_4$, weak acid

b) sodium ethoxide, C_2H_5ONa, strong base

c) sodium phosphate, Na_3PO_4, weak base

d) sodium hydrogen carbonate, weak base

10. Draw the lewis structure for the acid base reaction below (including products), showing where the electron pair acceptor moves, and labelling the lewic acid and the lewis base:
    a. Cl^{-} + $AlCl_3$

DO NOT COPY

    b. O^{2-} + CO_2

11. Write the equations for the ionization of the weak diprotic acid, carbonic acid, H_2CO_3.

12. For the reaction in aqueous solution between the diprotic weak acid, sulfurous acid, and sodium hydroxide write the overall neutralization equation

13. Write the reaction equations for the ionization in water of the weak triprotic acid, citric acid ($C_6H_5O_7H_3$).

14. Predict whether aqueous solutions of the following salts are neutral, acidic, or basic:

a) potassium iodide

b) sodium cyanide

c) ammonium dihydrogen phosphate

15. Show, using equations, why sodium acetate produces a basic solution in water.

16. Write the reaction equations for the dissociation of each of the following substances in water and explain, with the use of Brønsted-Lowry reaction equations, the acidity or basicity of the resulting solutions:

a) potassium bisulfate, $KHSO_4$, weak acid

b) ammonium chloride, weak acid

DO NOT COPY

c) sodium ethoxide, C_2H_5ONa, strong base

d) sodium phosphate, weak base