Types of Chemical Reactions

Classes of Chemical Compounds

Topics

- Naming chemical compounds
- Revision (Periodic Law)

- Types of chemical reactions

- Classes of inorganic compounds and their properties

Compounds

- substances composed of more than one element, chemically combined. A compound is represented by its chemical formula, a notation that uses atomic symbols with numerical subscripts to convey the relative proportion of atoms of different elements in the substance.

  E. g. HCl, H_2O, NH_3

- There are three fundamental kinds of chemical bonds between atoms - covalent bonds, ionic bonds and metallic bonds.

Which of the following shows how the atomic radius of the elements changes on crossing from left to right in the row of the Periodic Table from potassium to bromine?

K to Ca Sc to Zn Ga to Br

- **A** decrease increase decrease
- **B** decrease decrease increase
- **C** decrease decrease decrease
- **D** increase decrease increase
- **E** increase increase increase

The atomic number of magnesium is 12. Which electron configuration given below corresponds to the Mg^{2+} ion (in its ground state)?

- A. $1s^2 2s^2 2p^6 3s^2 3p^2$
- B. $1s^2 2s^2 2p^6 3s^2$
- C. $1s^2 2s^2 2p^6$
- D. $1s^2 2s^2 2p^6 3s^1$
- E. $1s^2 2s^2 2p^5 3s^1$

The alkali metals all react with water.

- **a Describe what happens as each of lithium, sodium and potassium reacts with water.**
- **b State the difference in the reactivity of these alkali metals with water.**
- **c Describe what you could do experimentally to show what the product(s) are.**

Which one of the following is **NOT** the correct formula for a lithium compound?

- **A** Li_2S
- **B** $LiCO_3$
- **C** CH_3CO_2Li
- **D** $LiHSO_4$
- **E** Li_3N

Organic and Inorganic Compounds

- Chemical compounds can be classified as organic or inorganic. Organic compounds are those formed by carbon and hydrogen (hydrocarbon) or carbon and hydrogen together with oxygen, nitrogen, and a few other elements.

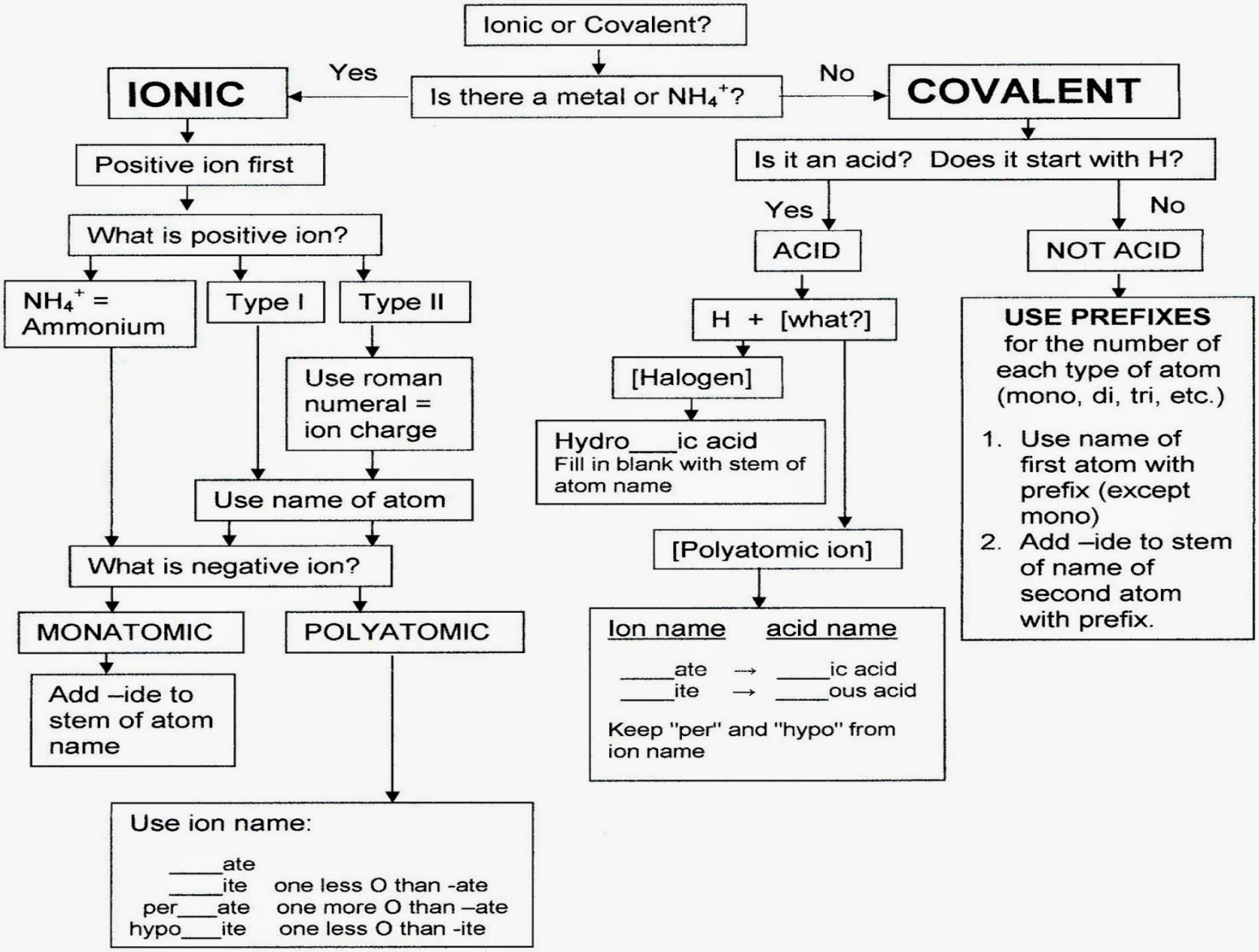
- Inorganic compounds are compounds composed of elements other than carbon. Except a few simple compounds of carbon, including carbon monoxide, carbon dioxide, carbonates and cyanides are generally considered to be inorganic.

Naming of Chemical Compounds

- Chemical nomenclature is the system of names that chemists use to identify compounds. Two classes of names exist: common names and systematic names. Common names: ammonia, water, baking soda, laughing gas, muriatic acid, table salt

- Systematic names precisely identify the chemical composition of the compound. The present system of inorganic chemical nomenclature was devised by the International Union of Pure and Applied Chemistry (IUPAC).

Naming Compounds



Inorganic Compounds

It's your turn...

1. **Name the compounds**

SO_2 $Fe(OH)_2$ HCl $HCl(aq)$ $CuCl_2$, HNO_3
Cl_2O_7 $BaSO_4$ KNO_3 H_2SiO_3 NH_4Cl
H_2SO_4 $NaHCO_3$ $(CuOH)_2CO_3$

2. **Write the formulas**

diphosphorus trioxide, iron dichloride, hydrogen sulfide, phosphoric acid, ammonia, sodium nitrite, phosphine, sulfurous acid, aluminium hydroxide, potassium dihydrocarbonate, sodium dichromate, sodium hexahydroxogermanate

How many of the following compounds are acidic, alkaline or amphoteric (react with both acids and alkalis)?

Al_2O_3 Cl_2O_7 CO_2 HCl H_3PO_4
K_2O KOH MgO

Na_2O NO_2 P_4O_{10} SiO_2 SO_2

- **A**. Acidic = 10; Amphoteric = 2; Alkaline = 4
- **B**. Acidic = 7; Amphoteric = 1; Alkaline = 5
- **C.** Acidic = 9; Amphoteric = 2; Alkaline = 2
- **D.** Acidic = 6; Amphoteric = 1; Alkaline = 6
- **E.** Acidic = 8; Amphoteric = 1; Alkaline = 4

Indicators of chemical reactions

- Emission of light or heat

- Formation of a gas

- Formation of a precipitate

- Color change

- Emission of odor

Describing Chemical Reactions

Atoms aren't created or destroyed. A chemical equation should be balanced.

- Sulfur reacts with oxygen to form/to give sulfur dioxide.
- One mole of sulfur reacts with one mole of oxygen forming/giving one mole of sulfur dioxide.
- Sulfur, a yellow solid, burns forming a colorless gas with an irritating smell.

sulfur + oxygen □ sulfur dioxide

$S_{(s)} + O_{2(g)}$ □ $SO_{2(g)}$

1. Synthesis Reactions

Реакция соединения

- occurs when two or more simple substances combine to produce a more complex substance.
- AKA: **Combination reaction**.

A + B □ AB

- ***HINT:*** *only one product.*

Examples of Synthesis Reactions

- $CO_2 + H_2O \rightarrow H_2CO_3$
- $4Fe + 3O_2 \rightarrow 2Fe_2O_3$
- $Li_2O + H_2O \rightarrow 2LiOH$

2. Decomposition Reactions

Реакция разложения

- occurs when a complex substance is broken down into two or more simpler substances.
- Heat is often used to aid in decomposition reactions – these reactions that employ heat are called **thermal decompositions**.
- Decompositions and synthesis reactions are opposites.

AB □ A + B

- ***HINT:*** only one reactant, two or more products.

Examples of Decomposition Reactions:

- NH_4NO_3 □ $N_2O + 2H_2O$
- $Ca(OH)_2$ □ $CaO + H_2O$
- $2H_2O_2$ □ $2H_2O + O_2$

3. Single Displacements

Реакция замещения

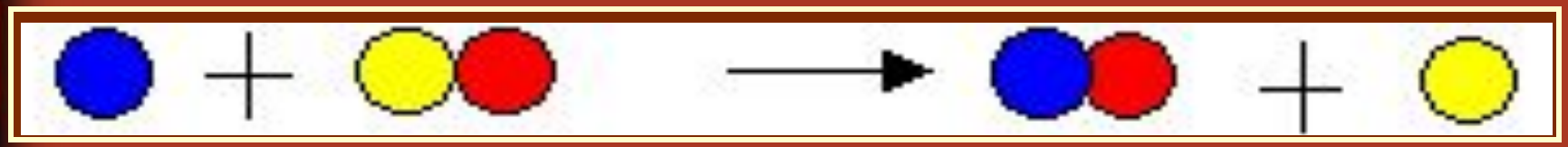
- occurs when a single element takes the place of one of the elements in a compound.
- AKA: Single Replacement

AB + Z □ ZB + A

- Metals displace metals while nonmetals displace nonmetals.
- ***HINT:*** The single mysterious loner moves into town and breaks up the happy couple!

Examples of Single Displacement Reactions

- $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$
- $2K + MgO \rightarrow K_2O + Mg$
- $2CuF + Ba \rightarrow BaF_2 + 2Cu$



Using the Activity Series

- The **activity series** (электрохимический ряд напряжений металлов) is a list of metals and hydrogen that are arranged in order of reactivity.

Li K Ba Ca Na Mg Al Zn Fe Ni Sn Pb H Cu Hg Ag Au

- The rule is that the element can only be displaced by another element that is to the left of it. This makes Lithium the strongest and Gold the weakest.

- There is also a halogen activity series – it is used to predict reactions with halides.

F Cl Br I

Using the Activity Series

You can use the activity series in three ways:

1) Straight forward Single Displacements
2) Reactions with Acids
3) Reactions with Water

- **Straight Forward Single Displacements**
  - Use the rule of "whoever is more to the left wins" to see if there is a reaction or not.
- **Reactions with Acids**
  - Acids contain hydrogen (positive like the metals). If you are to the left of hydrogen – you react and take its place – if you are to the right – there is no reaction.
- **Reactions with Water**
  - Only the first five elements (Li K Ba Ca Na) will react with water. It will form a hydroxide and hydrogen gas.

4. Double Displacements

Реакция обмена

- always involves two ionic compounds that switch partners with each other.
- Again, positive ions switch with positive ions (and/or vice-versa).

AB + XY □ AY + XB

HINT: Two couples switch partners at the dance.

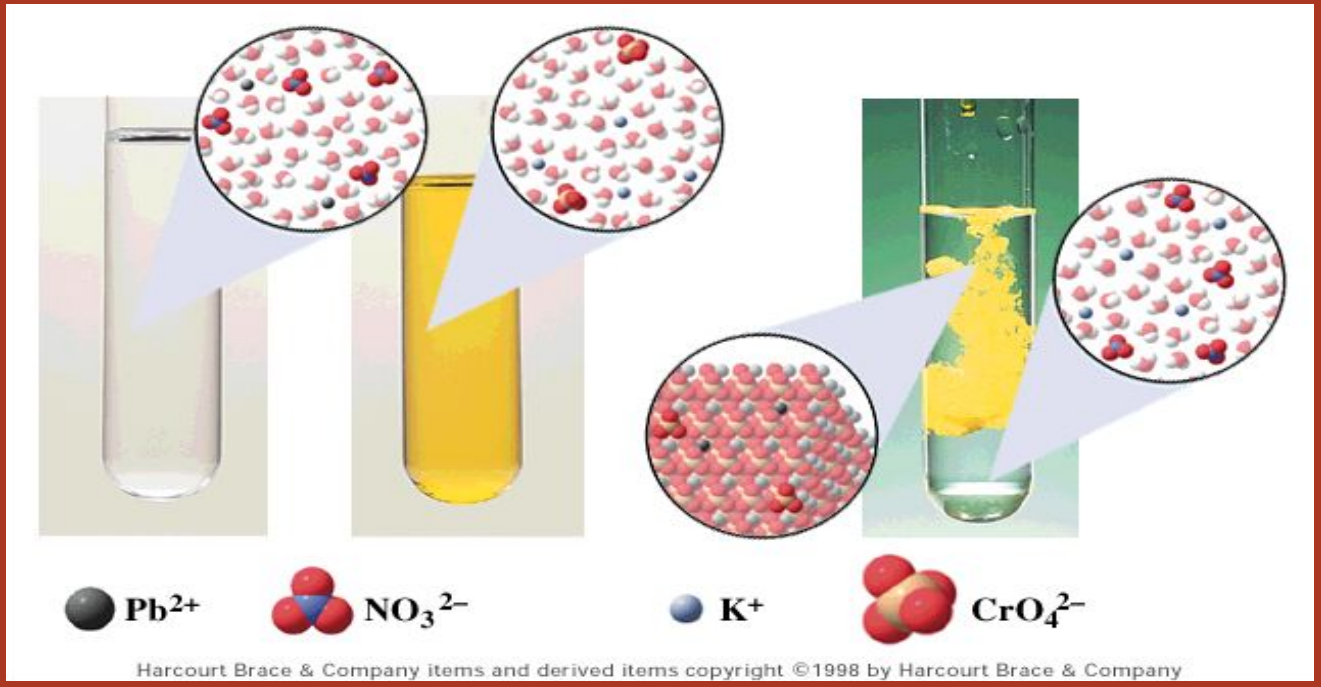
Examples of Double Displacement Reactions:

- $Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$
- $Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2SO_3$
- $2NaOH + H_2SO_4 \rightarrow 2H_2O + Na_2SO_4$

Indicators of occurring reactions

1) Precipitate – solid formed from two liquids.
2) Gas – some compounds form products that break down further into gases.
3) Water – results from a neutralization between an acid and a base.

$$Pb(NO_3)_2(aq) + K_2CrO_4(aq) \rightarrow PbCrO_4(s) + 2KNO_3(aq)$$



5. Combustion Reaction

Реакция горения

occurs when a substance (the "fuel") reacts very rapidly with oxygen to form carbon dioxide and water.

Combustion reactions release a good deal of energy in a very short period of time.

$$\text{Fuel} + O_2 \rightarrow CO_2 + H_2O$$

***HINT*: Something combines with oxygen to produce carbon dioxide and water.**

$$C_{10}H_8(s) + 12O_2(g) \rightarrow 10CO_2(g) + 4H_2O(g)$$

Incomplete Combustion

If a combustion occurs at a lower temperature, it may result in an incomplete combustion.

The products of an incomplete combustion are water, carbon dioxide, carbon monoxide and carbon (a solid residue).

The general equation is:

$$\text{Fuel} + O_2 \rightarrow H_2O + CO_2 + CO + C$$

It's your turn...

- $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$
- $Mg + O_2 \rightarrow MgO$
- $H_2O_2 \rightarrow H_2O + O_2$
- $Al + CuCl_2 \rightarrow Cu + AlCl_3$
- $Pb(NO_3)_2 + KI \rightarrow PbI_2 + KNO_3$

Oxides

Compounds of oxygen with other elements are called oxides.

NO_2, SO_2, H_2O, CO_2, N_2O_5, NO, N_2O are common non metal oxides, they have covalent bond structure.

Na_2O, FeO, Al_2O3, CaO, SiO_2, MgO, CuO, PbO are some common metal oxides they have ionic structure.

<u>Naming of Oxides</u>

They are named like binary compounds.

MgO : Magnesium oxide

SO_2 : Sulfur dioxide

P_2O_5 : Diphosphorus pentoxide

SnO_2 : Tin(IV) oxide

Classification of Oxides

1. Acidic Oxides

Oxygen rich compounds of non metals are called acidic oxides. SO_2, NO_2, P_2O_5, Cl_2O are examples.

Their solutions are acidic. They are known as acidic anhydrides.

Acidic oxide + water → Acid $P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$

2. Basic Oxides

Generally metal oxides are called basic oxides. Na_2O, CaO, MgO are examples.

Their solutions are basic. They are known as basic anhydrides.

Basic oxide + water → Base $MgO + H_2O \rightarrow Mg(OH)_2$

3. Mixed Oxides

Compounds that contain two oxides of the same metal are called mixed oxides. Fe_3O_4, Mn_3O_4, Pb_3O_4 are examples. They behave as if they are two separate oxides in chemical reactions.

Fe_3O_4 : $FeO*Fe_2O_3$: Iron (II, III) oxide

Bases

Compounds dissolving in water by producing OH^- ion are called bases.

They have slippery feeling. Many cleaning products contain bases.

$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

<u>Naming of Bases</u>

The word "hydroxide" is added after the name of metal ion in the naming of bases.

$Mg(OH)_2$: Magnesium hydroxide

KOH : Potassium hydroxide

NaOH : Sodium hydroxide

$Ba(OH)_2$: Barium hydroxide

Classification of Bases

According to Strength

Bases that ionize in water completely are said to be strong base. NaOH, KOH and LiOH are strong bases (alkalis).

Bases that ionize in water partially are called weak bases. $Fe(OH)_2$, $Al(OH)_3$ are example for weak bases.

Chemical Properties of Bases

- According to solubility bases conduct electricity.
- change the color of litmus paper to blue.
- react with acids and produce salt and water.
- Water insoluble bases decompose on heating to give metal oxides and water.

$2KOH(s) + H_2SO_4(l) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

$Mg(OH)_2 \rightarrow MgO + H_2O$

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Acids

Compounds dissolving in water by producing H^+ ion are called acids.

$HCl(g) \rightarrow H^+(aq) + Cl^-(aq)$ $H_2SO_4 \rightarrow 2H^+(aq) + SO_4^{-2}(aq)$

- They have sour taste.
- They change the color of litmus paper to red.
- Their aqueous solutions conduct electricity.
- They are corrosive substances.
- Most of them are soluble in water.

Naming of Acids

Acids containing two types of atoms are called binary acids. Their names follow the form *hydro* + *nonmetal name* + –ic + *acid*.

HCl : Hydrochloric acid

Acids containing oxygen atoms are called oxy acids. Their names follow the form –ic + acid, or –ous + acid.

HNO_3 : Nitric acid HNO_2 : Nitrous acid

Classification of Acids

According to Strength

- If an acid ionizes completely, it is an strong acid, and if it ionizes partially it is a weak acid.

Strong acids HCl, H_2SO_4, HNO_3

Weak acids H_2SO_3, HNO_2, H_2S, HCN

According to Number of Hydrogen Atoms

- According to number of H^+ ion produced acids are classified as monoprotic, diprotic or triprotic.
- *Monoprotic acids* HCl, HNO_3, HI, HBr, $HClO_4$
- *Diprotic acids* H_2SO_3, H_2S, H_2CO_3, H_2SO_4
- *Triprotic acids* H_3PO_4

Chemical Properties of Acids

- Acids ionize in water and conduct electricity, during the ionization heat is released.
- They change the color of indicators.
- They react with bases and produce salt and water, it is called neutralization reaction.

They react with basic oxides and some salts.

- They react with some metals and produce hydrogen gas.

$HNO_3(l) + KOH(s) \rightarrow KNO_3(aq) + H_2O(l)$

$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$

Amphoteric Compounds

Most of the compounds of Zn, Al, Cr, Sn, Pb, and Be are amphoteric compounds. Oxides and hydroxides of these metals have both acidic and basic characters.

They are insoluble in water and do not react with it.

ZnO, Al_2O_3 are oxides, and $Zn(OH)_2$, $Al(OH)_3$ are hydroxides.

$ZnO + 2HCl \rightarrow ZnCl_2 + H_2O$

$ZnO + 2NaOH \rightarrow Na_2ZnO_2 + 2H_2O$

ACIDS, ALKALIS, AND THE pH SCALE

The pH scale is a way of gauging the acidity or alkalinity of a solution. It is calculated using: $pH = -\log_{10}[H^+]$. Adding an acid to water increases the H^+ (H_3O^+) concentration, and decreases the OH^- concentration. An alkali does the opposite.

pH	H^+ CONCENTRATION (in moles per litre)	OH^- CONCENTRATION (in moles per litre)	EVERYDAY EXAMPLE
14	1×10^{-14}	1	Drain Cleaner
13	1×10^{-13}	0.1	Bleach
12	1×10^{-12}	0.01	Ammonia
11	1×10^{-11}	0.001	Soap
10	1×10^{-10}	1×10^{-4}	Antacid Tablets
9	1×10^{-9}	1×10^{-5}	Baking Soda
8	1×10^{-8}	1×10^{-6}	Seawater
7	1×10^{-7}	1×10^{-7}	Pure Water
6	1×10^{-6}	1×10^{-8}	Urine (average)
5	1×10^{-5}	1×10^{-9}	Black Coffee
4	1×10^{-4}	1×10^{-10}	Tomato Juice
3	0.001	1×10^{-11}	Soda
2	0.01	1×10^{-12}	Lemon Juice
1	0.1	1×10^{-13}	Stomach Acid
0	1	1×10^{-14}	Battery Acid

ALKALINE (Purple → Blue → Turquoise)

NEUTRAL (Green)

ACIDIC (Yellow → Orange → Red)

pH

pH is a numeric scale used to specify the acidity or basicity of an aqueous solution. It is approximately the negative of the logarithm to base 10 of the molar concentration, measured in units of moles per liter, of hydrogen ions. More precisely it is the negative of the logarithm to base 10 of the activity of the hydrogen ion.

$$pH = - \lg [H^+]$$

Salts

- Salts are ionic compounds of anions and cations: Na
  $CaCO_3$, $ZnBr_2$, $FeSO_4$…etc
- They are all crystalline solids.
- They have high melting and boiling points.
- Many of them are soluble in water and their aqueous solutions conduct electricity.

Naming of Salts

In the naming of salts first metal ion (positive ion) then name of negative ion is read.

$KMnO_4$ Potassium permanganate

Classification of Salts

A. Neutral Salts

are formed from the reactions of strong acids with strong bases.

$NaCl$, $LiNO_3$, KNO_3, Li_2SO_4 .

B. Acidic Salts

are formed from the reactions of strong acids with weak bases. Their solutions are acidic.

$FeCl_2$, $Zn(NO_3)_2$

C. Basic Salts

are formed from the reactions of weak acids with strong bases. Their solutions are basic.

$NaCN$, LiF, K_2CO_3, $K_2C_2O_4$

Chemical Properties of Salts

- Salts can react with metals according to activity strength.

$Zn(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Zn(NO_3)_2(aq)$

- Water soluble salts undergo displacement reaction.

$KCl(aq) + AgNO_3(aq) \rightarrow 2AgCl(s) + KNO_3(aq)$

- They may also react with acids under certain conditions.

$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$

The end