

7.10: Strong Acid Solutions that Water Contributes pH

Oxides are chemical compounds with one or more **oxygen** atoms combined with another element (e.g. Li_2O). Oxides are binary compounds of oxygen with another element, e.g., CO_2 , SO_2 , CaO , CO , ZnO , BaO_2 , H_2O , etc. These are termed as oxides because here, oxygen is in combination with only one element. Based on their acid-base characteristics oxides are classified as acidic, basic, **amphoteric** or neutral:

1. An oxide that combines with water to give an acid is termed as an acidic oxide.
2. The oxide that gives a base in water is known as a basic oxide.
3. An amphoteric solution is a substance that can chemically react as either acid or base.
4. However, it is also possible for an oxide to be neither acidic nor basic, but is a neutral oxide.

There are different properties which help distinguish between the three types of oxides. The term **anhydride** ("without water") refers to compounds that assimilate H_2O to form either an acid or a base upon the addition of water.

Acidic Oxides

Acidic oxides are the oxides of non-metals (**Groups 14-17**) and these **acid anhydrides** form acids with water:

- Sulfurous Acid



- Sulfuric Acid



- Carbonic Acid



Acidic oxides are known as acid anhydrides (e.g., sulfur dioxide is sulfurous anhydride and sulfur trioxide is sulfuric anhydride) and when combined with bases, they produce salts, e.g.,



Basic Oxides

Generally **Group 1** and **Group 2** elements form bases called base anhydrides or basic oxides e.g.,



Basic oxides are the oxides of metals. If soluble in water, they react with water to produce hydroxides (alkalies) e.g.,

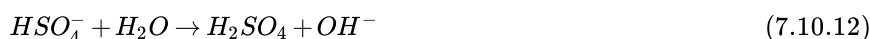


These metallic oxides are known as basic anhydrides. They react with acids to produce salts, e.g.,



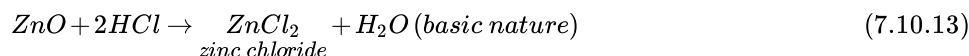
Amphoteric Oxides

An amphoteric solution is a substance that can chemically react as either acid or base. For example, when HSO_4^- reacts with water it will make both hydroxide and **hydronium** ions:

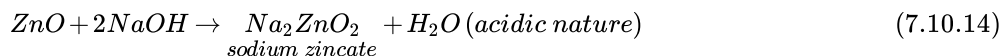


Amphoteric oxides exhibit both basic as well as acidic properties. When they react with an acid, they produce salt and water, showing basic properties. While reacting with alkalies they form salt and water showing acidic properties.

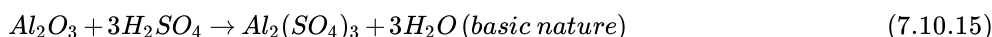
- For example ZnO exhibits basic behavior with HCl



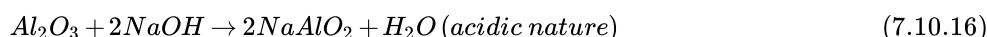
- and acidic behavior with $NaOH$



- Similarly, Al_2O_3 exhibits basic behavior with H_2SO_4



- and acidic behavior with $NaOH$



Neutral Oxides

Neutral oxides show neither basic nor acidic properties and hence do not form salts when reacted with acids or bases, e.g., carbon monoxide (CO); nitrous oxide (N₂O); nitric oxide (NO), etc., are neutral oxides.

Peroxides and Dioxides

Oxides: Group 1 metals react rapidly with oxygen to produce several different ionic oxides, usually in the form of M_2O . With the oxygen exhibiting an oxidation number of -2.



Peroxides: Often Lithium and Sodium reacts with excess oxygen to produce the peroxide, M_2O_2 . with the oxidation number of the oxygen equal to -1.



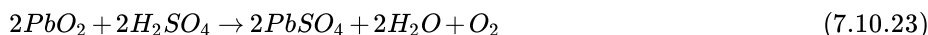
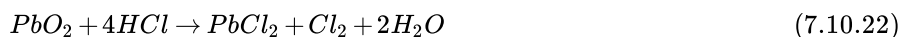
Superoxides: Often Potassium, Rubidium, and Cesium react with excess oxygen to produce the superoxide, MO_2 . with the oxidation number of the oxygen equal to -1/2.



A peroxide is a metallic oxide which gives hydrogen peroxide by the action of dilute acids. They contain more oxygen than the corresponding basic oxide, e.g., sodium, calcium and barium peroxides.

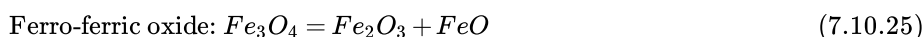
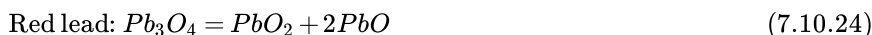


Dioxides like PbO_2 and MnO_2 also contain higher percentage of oxygen like peroxides and have similar molecular formulae. These oxides, however, do not give hydrogen peroxide by action with dilute acids. Dioxides on reaction with concentrated HCl yield Cl_2 and on reacting with concentrated H_2SO_4 yield O_2 .

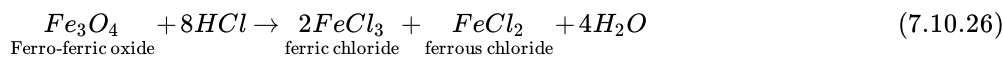


Compound Oxides

Compound oxides are metallic oxides that behave as if they are made up of two oxides, one that has a lower oxidation and one with a higher oxidation of the same metal, e.g.,



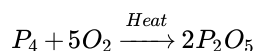
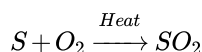
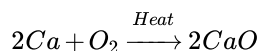
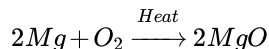
On treatment with an acid, compound oxides give a mixture of salts.



Preparation of Oxides

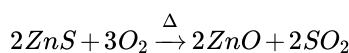
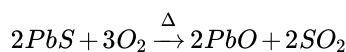
Oxides can be generated via multiple reactions. Below are a few.

By direct heating of an element with oxygen: Many metals and non-metals burn rapidly when heated in oxygen or air, producing their oxides, e.g.,

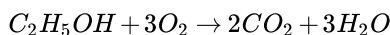


By reaction of oxygen with compounds at higher temperatures: At higher temperatures, oxygen also reacts with many compounds forming oxides, e.g.,

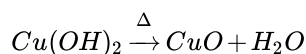
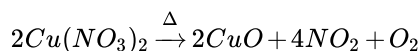
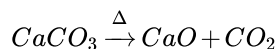
- sulfides are usually oxidized when heated with oxygen.



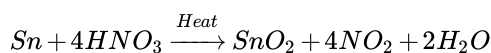
- When heated with oxygen, compounds containing carbon and hydrogen are oxidized.



- By thermal decomposition of certain compounds like hydroxides, carbonates, and nitrates



By oxidation of some metals with nitric acid

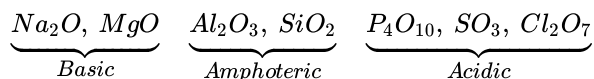


By oxidation of some non-metals with nitric acid



Trends in Acid-Base Behavior

The oxides of elements in a period become progressively more acidic as one goes from left to right in a period of the periodic table. For example, in third period, the behavior of oxides changes as follows:



If we take a closer look at a specific period, we may better understand the acid-base properties of oxides. It may also help to examine the physical properties of oxides, but it is not necessary. Metal oxides on the left side of the periodic table produce basic solutions in water (e.g. Na_2O and MgO). Non-metal oxides on the right side of the periodic table produce acidic solutions (e.g.

Cl_2O , SO_2 , P_4O_{10}). There is a trend within acid-base behavior: basic oxides are present on the left side of the period and acidic oxides are found on the right side.

Aluminum oxide shows acid and basic properties of an oxide, it is amphoteric. Thus Al_2O_3 entails the marking point at which a change over from a basic oxide to acidic oxide occurs. It is important to remember that the trend only applies for oxides in their highest oxidation states. The individual element must be in its highest possible oxidation state because the trend does not follow if all oxidation states are included. Notice how the amphoteric oxides (shown in blue) of each period signify the change from basic to acidic oxides,

Groups						
1	2	3	14	15	16	17
Li	Be	B	C	N	O	F
Na	Mg	Al	Si	P	S	Cl
K	Ca	Ga	Ge	As	Se	Br
Rb	Sr	In	Sn	Sb	Te	I
Cs	Ba	Tl	Pb	Bi	Po	At

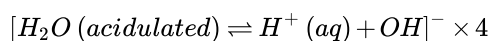
The figure above show oxides of the *s*- and *p*-block elements.
 purple: basic oxides blue: amphoteric oxides pink: acidic oxides

Problems

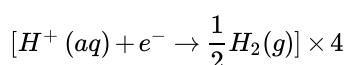
1. Can an oxide be neither acidic nor basic?
2. $\text{Rb} + \text{O}_2 (\text{excess}) \rightarrow ?$
3. $\text{Na} + \text{O}_2 \rightarrow ?$
4. BaO_2 is which of the following: hydroxide, peroxide, or superoxide?
5. What is an amphoteric solution?
6. Why is it difficult to obtain oxygen directly from water?

Solutions

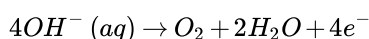
1. Yes, an example is carbon monoxide (CO). CO doesn't produce a salt when reacted with an acid or a base.
2. $\text{Rb} + \text{O}_2 (\text{excess}) \rightarrow \text{RbO}_2$
 With the presence of excess oxygen, Rubidium forms a superoxide. Please review section regarding basic oxides above for more detail.
3. $2\text{Na} + \text{O}_2 \rightarrow \text{Na}_2\text{O}$
 Note: The problem does not specify that the oxygen was in excess, so it cannot be a peroxide. Please review section regarding basic oxides for more detail.
4. BaO_2 is a peroxide. Barium has an oxidation state of +2 so the oxygen atoms have oxidation state of -1. As a result, the compound is a peroxide, but more specifically referred to as barium peroxide.
5. An amphoteric solution is a substance that can chemically react as either acid or base. See section above on Properties of Amphoteric Oxides for more detail.
6. Water as such is a neutral stable molecule. It is difficult to break the covalent O-H bonds easily. Hence, electrical energy through the electrolysis process is applied to separate dioxygen from water. When a small amount of acid is added to water ionization is initiated which helps in electrochemical reactions as follows.



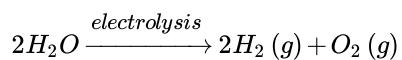
At cathode:



At anode:



Net reaction:



Oxygen can thus be obtained from acidified water by its electrolysis.

References

1. Petrucci, Ralph, William Harwood, Jeffrey Madura, and Geoffrey Herring. General Chemistry: principles and modern applications. 9th Edition. New Jersey, NJ: Prentice Hall, 2007. 877. Print.
2. <http://www.wou.edu/las/physci/ch412/oxides.html>
3. www.transtutors.com/chemistry...ts/oxides.aspx

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