

**THE PROPERTIES OF NATURAL RESOURCES***15 minutes, Video*Distributed by **BENCHMARK MEDIA****FOR USE IN:** Chemistry**LEVEL:** Grades 9-14**EDUCATIONAL ADVISOR:** Dr. O. Roger Anderson, Columbia University: Professor Natural Sciences, Teachers College; Senior Research Scientist, Lamont-Doherty Earth Observatory**EDUCATIONAL OBJECTIVES:**

To help the student understand these key concepts about the properties of natural resources:

- the nature of economically important raw materials such as crude oil, air and metal ores
- the principles of the separation of mixtures by distillation
- the properties of the distillation products of crude oil and liquid air
- the classification of oxides of metals and non-metals
- the reactivity of metals and the methods of their extraction
- reduction and oxidation in metal extraction

**BACKGROUND INFORMATION:**

Mixtures can be separated into their component parts, such as the separation of crude oil by fractional distillation. Upon separation of crude oil, it can be noted that it is made up of a mixture of hydrocarbons, compounds that contain both hydrogen and carbon. These hydrocarbons have different weights and the differences in their boiling points are the basis for their separation. Lower boiling point liquids vaporize before higher boiling point liquids and will collect first as fractions in the distillation process.

Oxygen is a gas that makes up approximately 21% of the earth's atmosphere. It reacts with both metals and nonmetals. Its reaction with metals produces metal oxides that react with water to form either soluble or insoluble hydroxides. The soluble hydroxides are known as basic anhydrides because they form compounds that test basic. Nonmetal oxides that are formed from oxygen combining with water will react with water to form acids. These nonmetal oxides are known as acid anhydrides.

Nitrogen is a gas that makes up approximately 78% of the earth's atmosphere. It differs from oxygen in that it is less reactive as evidenced by the extinction of a glowing splint when it is put into nitrogen. Air can be liquefied in liquid nitrogen and upon warming, two gases are emitted, nitrogen and oxygen.

Most metals are found combined with other elements and to obtain them in their pure elemental form, it is necessary to separate them through chemical processes such as reduction. This process is often used in the separation of metal oxides where hydrogen or carbon, act as reducing agents.

**CONTENT OF THE VIDEO:**

The video contains the following 3 key concepts. To play only concepts 2 or 3, fast forward until you see its title.

	running time min:sec
<b>1. Fractional Distillation of Petroleum</b>	<b>5:00</b>
<b>2. Oxygen and Nitrogen</b>	<b>5:25</b>
<b>3. Reducing Metal Oxides</b>	<b>4:25</b>

The concepts are illustrated with imaginative demonstrations, which are too dangerous, costly, or complicated to be done in the classroom. Computer animation, graphics, positioned captions, and live photography clarify and provide context for the concepts.

**Fractional Distillation of Petroleum**

### **The composition of crude oil**

Crude oil contains a mixture of hydrocarbon compounds with carbon chains of different lengths.

### **Simple laboratory distillation of crude oil**

Heating crude oil gently vaporizes the hydrocarbons with the lowest boiling points. The vapor is cooled and condensed to give a *fraction* with a low boiling point. Fractions with higher boiling points are obtained by increasing the temperature.

### **Improving the fractionating process**

Adding a fractionating column and Liebig condenser allows the crude oil to be fractionally distilled more efficiently. Separation of crude oil into fractions takes place in the fractionating column.

### **Industrial distillation of crude oil**

The oil industry uses [fractional distillation](#). In an industrial fractionating tower, fractions of crude oil with small molecules collect at the top while the fractions with the largest molecules run off near the bottom.

## **Oxygen and Nitrogen**

### **Burning substances in oxygen**

Oxygen relights a glowing splint. Non-metals burn in oxygen to produce acidic oxides. Reactive metals produce alkalis when they burn in oxygen. About one-fifth of the atmosphere is oxygen.

### **Properties of nitrogen**

A demonstration of the unreactive nature of nitrogen gas and the use of liquid nitrogen as a coolant.

### **Distilling liquefied air**

Liquid nitrogen is used to liquefy air. As the liquid air warms up, nitrogen boils off first, followed by oxygen, which has a slightly higher boiling point.

## **Reducing Metal Oxides**

### **Finding metals in the Earth's crust**

The occurrence of metals in their native state and as ores.

### **Reducing copper oxide**

Hot copper oxide is reduced in hydrogen gas. Safety precautions are stressed. The chemical changes are explained in terms of reduction and oxidation.

### **Another way of reducing copper oxide**

Using carbon as the reducing agent is a safer way of extracting copper from its oxide. The reaction is again described in 'redox' terms.

### **Reducing oxides of other metals**

The reaction of carbon with other metal oxides is investigated. Lead is displaced from its oxide, but with iron oxide nothing happens.

## **AFTER SHOWING THE VIDEO:**

### **Fractional Distillation**

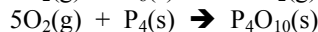
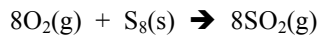
Substances can be separated by different methods. A sample of crude oil requires a process known as fractional distillation that relies on a difference in the boiling point of the fractions. Boiling point is defined as the temperature at which the vapor pressure exerted by the liquid equals the external pressure acting on the surface of the liquid. "Normal" boiling points are determined for substances at 1 atmosphere of pressure.

There is a general relationship between the mass of a substance and its boiling point, that is, the heavier the substance, the higher the boiling point. This general statement applies to crude oil because its fractions are all hydrocarbons and the hydrocarbons with the lower masses will vaporize first. Those substances that vaporize first have lower boiling points.

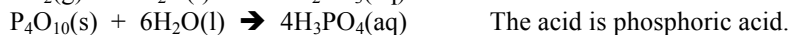
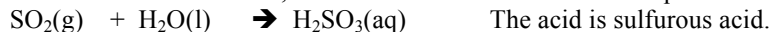
### **Properties of Oxygen**

Oxygen is a gas that supports combustion, or burning, as evidenced by a glowing splint bursting into

flames when the splint is inserted into oxygen gas. Oxygen also reacts with nonmetals to form nonmetal oxides such as sulfur dioxide, or phosphorus to form tetraphosphorus decoxide. The equations follow for these reactions.

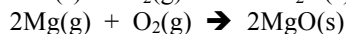
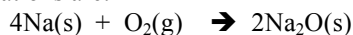


When water is added to the oxides, acidic solutions are formed. The equations are:



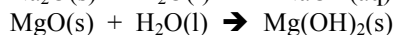
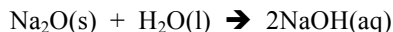
Likewise, oxygen also reacts with metals to form metal oxides such as sodium oxide and magnesium oxide.

The equations are:



However, when the metal oxides react with water the solution formed is basic or alkaline, and not acidic like the nonmetal oxides with water.

The equations are:



Note that "aq" follows NaOH, but "s" follows Mg(OH)<sub>2</sub>. NaOH is soluble in water and therefore forms a solution of the solid in water (aqueous). Mg(OH)<sub>2</sub> is considered insoluble in water and therefore its state is solid. There are enough hydroxide ions, OH<sup>-</sup>, though, to cause Universal indicator to show a basic solution.

### Properties of Nitrogen

Nitrogen does not support combustion like oxygen does, and therefore a glowing splint is extinguished immediately in nitrogen. Liquid nitrogen, whose temperature is -210°C, is cold enough to liquefy air. Since the two main gases in air are nitrogen (78%) and oxygen (21%), both of these gases will be given off as liquid air boils. Nitrogen with a lower boiling point, -196°C, is given off first, followed by oxygen whose boiling point is -183°C.

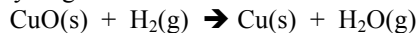
### Reduction to Free Metals

How free metals are obtained from their metal ores depends on how strongly the metals ions are bonded to the negative ions. The stronger the bond, the more energy is required to reduce the metals. More active metals such as lithium, potassium, calcium, sodium, magnesium, and aluminum have the strongest bonding and electrolysis is used to obtain the pure metal from the molten salt. The least reactive metals such as gold, silver, and platinum occur in the free state, and not as metal ores. They require no reduction.

The reducing agent that is utilized depends on the reaction. Carbon is used for the reduction of metal ores containing manganese, zinc, chromium, and iron which are less reactive than the metals listed above. Other reducing agents such as hydrogen, iron, and aluminum are also used. Hydrogen can be used to reduce metal ores containing lead or copper.

### Reduction of Copper (II) Oxide, CuO.

1. With hydrogen



In the reaction above copper in copper (II) oxide, CuO, has an oxidation state of 2+. It is reduced to Cu metal whose oxidation state is 0. Hydrogen, H<sub>2</sub>, has an oxidation state of 0 and it is oxidized to hydrogen (in water) with an oxidation state of 1+. The process of reduction involves a gain of electrons and oxidation involves a loss of electrons. Electrons are neither created nor destroyed in chemical reactions so the processes of oxidation and reduction occur simultaneously.

2. With carbon



In the reaction above  $\text{Cu}^{2+}$  is again reduced to  $\text{Cu}^0$ . Carbon with an oxidation state of 0 is oxidized to carbon in carbon dioxide with an oxidation state of 4+.

**There were several questions raised in the video that were not answered.**

1. What is the pattern for metal and nonmetal oxides when they combine with water?

Metal oxides that form soluble hydroxides when combined with water are called basic anhydrides because they form solutions that test basic. Nonmetal oxides that combine with water are called acid anhydrides and they form acids.

2. Why does carbon reduce copper and lead oxides, but not iron oxide?

In the reactivity series of metals, copper and lead are less reactive than iron. Therefore, carbon is unable to reduce more reactive metal oxides such as iron oxide and zinc oxide.

### **EXPLORING AND INVESTIGATING**

1. There are different separation techniques. One such technique is chromatography.

Obtain a magic marker and some finger nail polish remover. Place a small dot of marker on the end of a narrow strip of paper towel. Place the end of the towel so the dot is just submerged in a small amount of nail polish remover. Explain what you observe. Try different brands of markers.

2. Do some research to determine the gases produced from carbon and nitrogen each reacting with oxygen. Write the equations. Also, what acids are produced from each of these nonmetal oxides when they react with water. Write the equations.

3. What is the reactivity series of metals? Make a list of the reactivity series. How can this list help understand the ability of carbon and hydrogen to reduce some metal ores and not others?

**Caution:** observe all safety regulations of your school when doing experiments in the laboratory. Check with the appropriate officer in your school before doing these experiments.

**Guide written by: Dr. Julie Ealy and James Ealy, Teachers College, Columbia University**

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**BENCHMARK MEDIA** 569 NORTH STATE ROAD, BRIARCLIFF MANOR, NY 10510  
TEL: 914/762-3838, 1/800-438-5564 FAX: 914/762-3895 E-MAIL: benchmedia@aol.com