Group16 Elements

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In the 19th century, Jons Jacob Berzelius suggested calling the elements in group 16 "amphigens", as the elements in the group formed amphid salts (salts of oxyacids) The term received some use in the early 1800s but is now obsolete. The name *chalcogen* comes from the Greek words *χαλκος* (chalkos, literally "copper"), and *γενές* (genes, born, gender, kindle). It was first used in 1932 by Wilhelm Biltz's group at the University of Hanover, where it was proposed by Werner Fischer. The word "chalcogen" gained popularity in Germany during the 1930s because the term was analogous to "halogen". Although the literal meanings of the Greek words imply that *chalcogen* means "copper-former", this is misleading because the chalcogens have nothing to do with copper in particular.

. "Ore-former" has been suggested as a better translation, as the vast majority of metal ores are chalcogenides and the word *χαλκος* in ancient Greek was associated with metals and metal-bearing rock in general; copper, and its alloy bronze, was one of the first metals to be used by humans.

Oxygen's name comes from the Greek words *oxy genes*, meaning "acid-forming". Sulfur's name comes from either the Latin word *sulfurium* or the Sanskrit word *sulvere*; both of those terms are ancient words for sulfur. Selenium is named after the Greek goddess of the moon, Selene, to match the previously-discovered element tellurium, whose name comes from the Latin word *telus*, meaning earth. Polonium is named after Marie Curie's country of birth, Poland. Livermorium is named for the Lawrence Livermore National Laboratory

- The oxygen family, also called the chalcogens, consists of the elements found in **Group 16** of the periodic table and is considered among the main group elements. It consists of the elements oxygen, sulfur, selenium, tellurium and polonium. These can be found in nature in both free and combined states.

- **Properties and Periodic Trends**
- All elements of the oxygen family have 6 electrons in their outermost shells. The electron configurations for each element are given below:
- **Oxygen**: $1s^2\ 2s^2\ 2p^4$
- **Sulfur**: $1s^2\ 2s^2p^6\ 3s^2p^4$
- **Selenium**: $1s^2\ 2s^2p^6\ 3s^2p^6d^{10}\ 4s^2p^4$
- **Tellurium**: $1s^2\ 2s^2p^6\ 3s^2p^6d^{10}\ 4s^2p^6d^{10}\ 5s^2p^4$
- **Polonium**: $1s^2\ 2s^2p^6\ 3s^2p^6d^{10}\ 4s^2p^6d^{10}f^{14}\ 5s^2p^6d^{10}\ 6s^2p^4$
- Note: The electron configuration can be written in noble gas notation, a shorthand option. This is accomplished putting the symbol for the noble gas preceding the valence electrons in brackets and listing the electron configuration for the valence electrons.

- Metallic character increases down the group, with tellurium classified as a metalloid and polonium as a metal. Melting point, boiling point, density, atomic radius, and ionic radius all increase down the group. Ionization energy decreases down the group. The most common oxidation state is -2; however, sulfur can also exist at a +4 and +6 state, and +2, +4, and +6 oxidation states are possible for Se, Te, and Po

Properties
Atomic and physical

Z	Element	No. of electrons/shell
8	oxygen	2, 6
16	sulfur	2, 8, 6
34	selenium	2, 8, 18, 6
52	tellurium	2, 8, 18, 18, 6
84	polonium	2, 8, 18, 32, 18, 6
116	livermorium	2, 8, 18, 32, 32, 18, 6 (predicted)

Element	Melting point (Celsius)	Boiling point (Celsius)
Oxygen	−219	−183
Sulfur	120	445
Selenium	221	685
Tellurium	450	988
Polonium	254	962

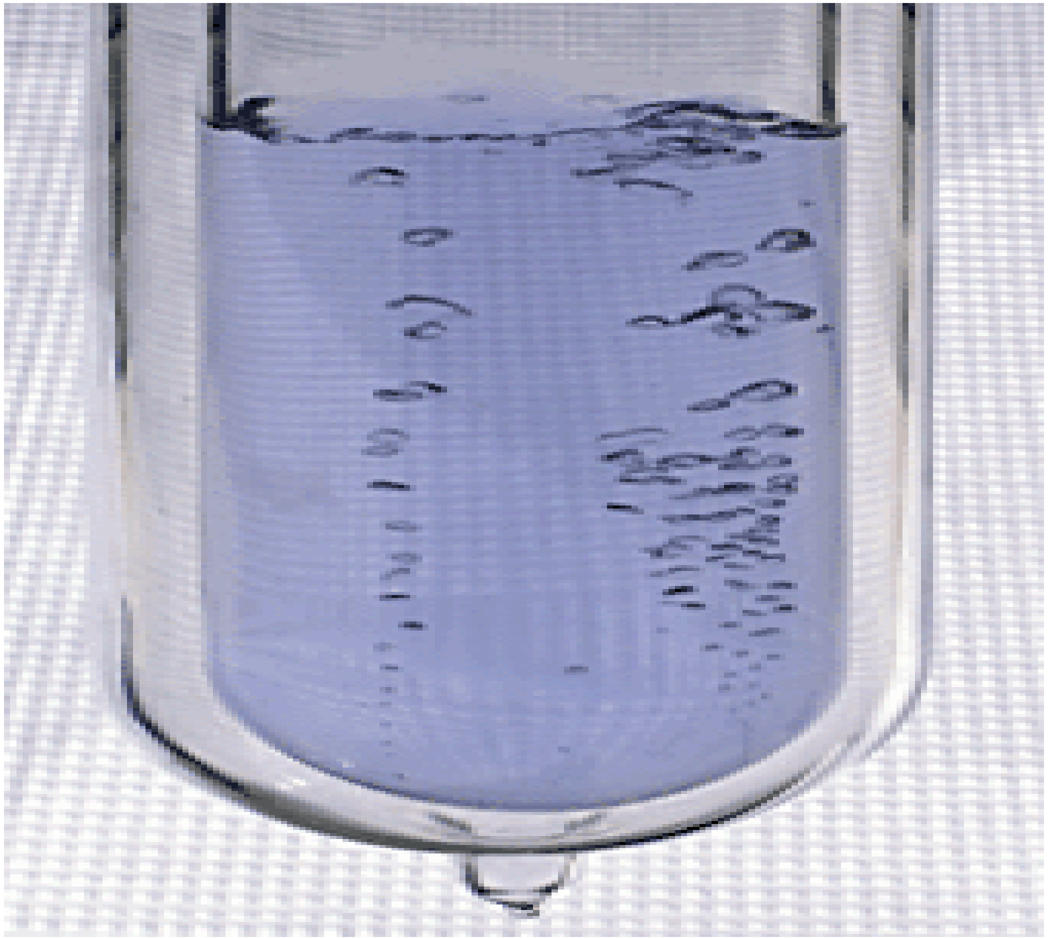
Element	Density at STP (g/cm^3)
Oxygen	0.00143
Sulfur	2.07
Selenium	4.3
Tellurium	6.24
Polonium	9.2

Oxygen

Oxygen is a gas at room temperature and 1 atm, and is colorless, odorless, and tasteless. It is the most abundant element by mass in both the Earth's crust and the human body. It is second to nitrogen as the most abundant element in the atmosphere. There are many commercial uses for oxygen gas, which is typically obtained through fractional distillation. It is used in the manufacture of iron, steel, and other chemicals. It is also used in water treatment, as an oxidizer in rocket fuel, for medicinal purposes, and in petroleum refining.

Oxygen has two allotropes, ***O_2 and O_3.*** In general, O_2 (or dioxygen) is the form referred to when talking about the elemental or molecular form because it is the most common form of the element. The O_2 bond is very strong, and oxygen can also form strong bonds with other elements. However, compounds that contain oxygen are considered to be more thermodynamically stable than O_2.

The latter allotrope, ozone, is a pale-blue poisonous gas with a strong odor. It is a very good oxidizing agent, stronger than dioxygen, and can be used as a substitute for chlorine in purifying drinking water without giving the water an odd taste. However, because of its unstable nature it disappears and leaves the water unprotected from bacteria. **Ozone at very high altitudes in the atmosphere is responsible for protecting the Earth's surface from ultraviolet radiation**; however, at lower altitudes it becomes a major component of smog.



Oxygen (O)
Diatomic nonmetal

Oxygen's primary oxidation states are -2, -1, 0, and -1/2 (in O_2^-), but **-2** is the most common. Typically, compounds with oxygen in this oxidation state are called **oxides**. When oxygen reacts with metals, it forms oxides that are mostly ionic in nature. These can dissolve in water and react to form hydroxides; they are therefore called **basic anhydrides** or **basic oxides**. Nonmetal oxides, which form covalent bonds, are simple molecules with low melting and boiling points.

Compounds with oxygen in an oxidation state of -1 are referred to as **peroxides**. Examples of this type of compound include Na_2O_2 and BaO_2. When oxygen has an oxidation state of -1/2, as in O_2^-, the compound is called a **superoxide**

Oxygen is rarely the central atom in a structure and can never bond with more than 4 elements due to its small size and its inability to create an expanded valence shell. Oxygen reacts with hydrogen to form water, which is extensively hydrogen-bonded, has a large dipole moment, and is considered an universal solvent.

There are a wide variety of oxygen-containing compounds, both organic and inorganic: oxides, peroxides and superoxides, alcohols, phenols, ethers, and carbonyl-containing compounds such as aldehydes, ketones, esters, amides, carbonates, carbamates, carboxylic acids and anhydrides.

Sulfur

Sulfur is a solid at room temperature and 1 atm pressure. It is usually yellow, tasteless, and nearly odorless. It is the sixteenth most abundant element in Earth's crust. It exists naturally in a variety of forms, including elemental sulfur, sulfides, sulfates, and **organosulfur** compounds. Since the 1890s, sulfur has been mined using the Frasch process, which is useful for recovering sulfur from deposits that are under water or quicksand. Sulfur produced from this process is used in a variety of ways including in vulcanizing rubber and as fungicide to protect grapes and strawberries.

Sulfur is unique in its ability to form a ***wide range of allotropes***, more than any other element in the periodic table. The most common state is the solid S_8 ring, as this is the most thermodynamically stable form at room temperature. Sulfur exists in the gaseous form in five different forms (S, S_2, S_4, S_6, and S_8). In order for sulfur to convert between these compounds, sufficient heat must be supplied.

Sulfur (S)
16 Polyatomic nonmetal

Two common oxides of sulfur are sulfur dioxide (SO_2) and sulfur trioxide (SO_3). *Sulfur dioxide is formed when sulfur is combusted in air, producing a toxic gas with a strong odor. These two compounds are used in the production of sulfuric acid, which is used in a variety of reactions. Sulfuric acid is one of the top manufactured chemicals in the United States, and is primarily used in the manufacture of fertilizers.*

Sulfur also exhibits a wide range of oxidation states, with values ranging from -2 to +6. *It is often the central ion in a compound and can easily bond with up to 6 atoms. In the presence of hydrogen it forms the compound hydrogen sulfide,* ***H_2S****, a poisonous gas incapable of forming hydrogen bonds and with a very small dipole moment. Hydrogen sulfide can easily be recognized by its strong odor that is similar to that of rotten eggs, but this smell can only be detected at low, nontoxic concentrations. This reaction with hydrogen epitomizes how differently oxygen and sulfur act despite their common valence electron configuration and common nonmetallic properties.*

A variety of sulfur-containing compounds exist, many of them organic. The prefix ***thio-*** in from of the name of an oxygen-containing compound means that the oxygen atom has been substituted with a sulfur atom. General categories of sulfur-containing compounds include **thiols (mercaptans), thiophenols, organic sulfides (thioethers), disulfides, thiocarbonyls, thioesters, sulfoxides, sulfonyls, sulfamides, sulfonic acids, sulfonates, and sulfates.**

Selenium

Selenium appears as a red or black amorphous solid, or a red or grey crystalline structure; the latter is the most stable. Selenium has properties very similar to those of sulfur; however, it is more metallic though it is still classified as a nonmetal. It acts as a **semiconductor** and therefore is often used in the manufacture of rectifiers, which are devices that convert alternating currents to direct currents. Selenium is also **photoconductive**, which means that in the presence of light the electrical conductivity of selenium increases. It is also used in the drums of laser printers and copiers. In addition, it has found increased use now that lead has beenremoved from plumbing brasses.

Selenium (Se)
34 Polyatomic nonmetal

- It is rare to find selenium in its elemental form in nature; it must typically be removed through a refining process, usually involving copper. It is often found in soils and in plant tissues that have bioaccumulated the element. In large doses, the element is toxic; however, many animals require it as an essential micronutrient. Selenium atoms are found in the enzyme glutathione peroxidase, which destroys lipid-damaging peroxides. In the human body it is an essential cofactor in maintaining the function of the thyroid gland. In addition, **some research has shown a correlation between selenium-deficient soils and an increased risk of contracting the HIV/AIDS virus**

- **Tellurium**

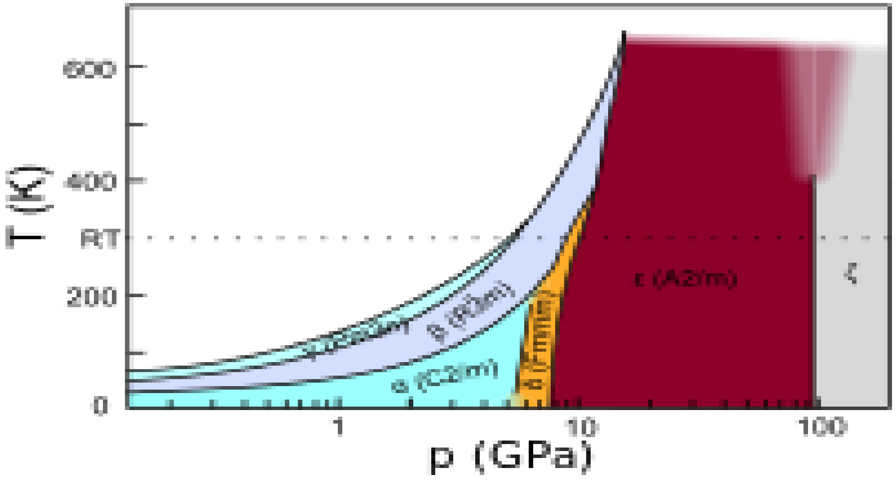
- Tellurium is the metalloid of the oxygen family, with a silvery white color and a metallic luster similar to that of tin at room temperature. Like selenium, it is also displays **photoconductivity**. Tellurium is an extremely rare element, and is most commonly found as a telluride of gold. It is often used in metallurgy in combination with copper, lead, and iron. In addition, it is used in solar panels and memory chips for computers. It is not toxic or carcinogenic; however, when humans are exposed to too much of it they develop a **garlic-like smell** on their breaths.

Tellurium (Te)
52 Metalloid

- **Polonium**
- Polonium is a **very rare, radioactive metal**. There are 33 different isotopes of the element and all of the isotopes are radioactive. It exists in a variety of states, and has two metallic allotropes. It dissolves easily into dilute acids. Polonium does not exist in nature in compounds, but it can form synthetic compounds in the laboratory. It is used as an alloy with beryllium to act as a neutron source for nuclear weapons.
- Polonium is a **highly toxic element**. The radiation it emits makes it very dangerous to handle. It can be immediately lethal when applied at the correct dosage, or cause cancer if chronic exposure to the radiation occurs. Methods to treat humans who have been contaminated with polonium are still being researched, and it has been shown that chelation agents could possibly be used to decontaminate humans.

Allotropes

Oxygen's most common allotrope is diatomic oxygen, or O_2, a reactive paramagnetic molecule that is ubiquitous to aerobic organisms and has a blue color in its liquid state. Another allotrope is O_3, or ozone, which is three oxygen atoms bonded together in a bent formation. There is also an allotrope called tetraoxygen, or O_4, and six allotropes of solid oxygen including "red oxygen", which has the formula O_8.



Phase diagram for solid oxygen

- Sulfur has over **20 known allotropes**, which is more than any other element except carbon. The most common allotropes are in the form of eight-atom rings, but other molecular allotropes that contain as few as two atoms or as many as 20 are known. Other notable sulfur allotropes include rhombic sulfur and monoclinic sulfur. Rhombic sulfur is the more stable of the two allotropes. Monoclinic sulfur takes the form of long needles and is formed when liquid sulfur is cooled to slightly below its melting point. The atoms in liquid sulfur are generally in the form of long chains, but above 190° Celsius, the chains begin to break down. If liquid sulfur above 190°Celsius is frozen very rapidly, the resulting sulfur is amorphous or "plastic" sulfur. Gaseous sulfur is a mixture of diatomic sulfur (S_2) and 8-atom rings.

Selenium has at least **five known allotropes.** The gray allotrope, commonly referred to as the "metallic" allotrope, despite not being a metal, is stable and has a hexagonal crystal structure. The gray allotrope of selenium is soft, with a Mohs hardness of 2, and brittle. The four other allotropes of selenium are metastable. These include two monoclinic red allotropes and two amorphous allotropes, one of which is red and one of which is black. The red allotrope converts to the red allotrope in the presence of heat. The gray allotrope of selenium is made from spirals on selenium atoms, while one of the red allotropes is made of stacks of selenium rings (Se_8).

Tellurium is not known to have any allotropes, although its typical form is hexagonal. Polonium has two allotropes, which are known as α-polonium and β-polonium. α-polonium has a cubic crystal structure and converts the rhombohedral β-polonium at 36 °C.

The chalcogens have varying crystal structures. Oxygen's crystal structure is monoclinic, sulfur's is orthorhombic, selenium and tellurium have the hexagonal crystal structure, while polonium has a cubic crystal structure.

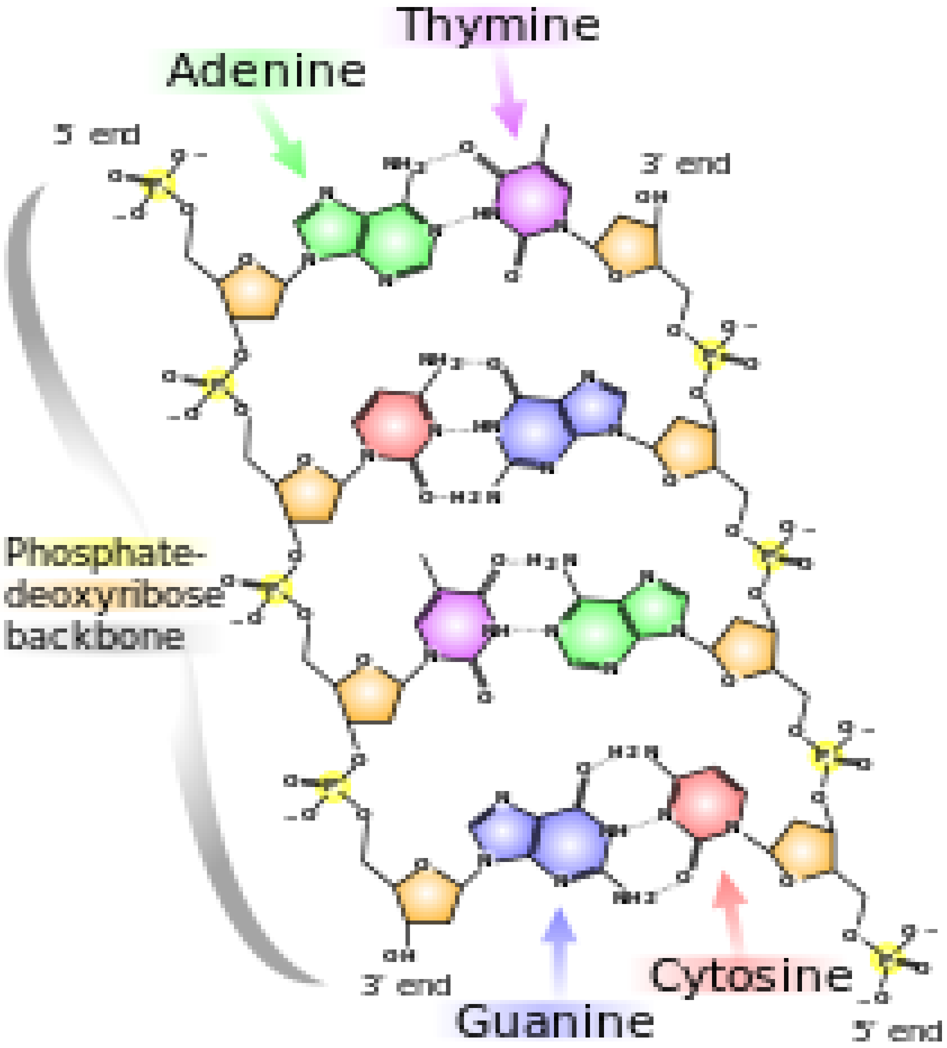
Applications

Steelmaking is the most important use of oxygen; 55% of all oxygen produced goes to this application. The chemical industry also uses large amounts of oxygen; 25% of all oxygen produced goes to this application. The remaining 20% of oxygen produced is mostly split between medical use, water treatment (as oxygen kills some types of bacteria), rocket fuel (in liquid form), and metal cutting.

Most sulfur produced is transformed into sulfur dioxide, which is further transformed into sulfuric acid, a very common industrial chemical. Other common uses include being a key ingredient of gunpowder and Greek fire, and being used to change soil pH.[6] Sulfur is also mixed into rubber to vulcanize it. Sulfur is used in some types of concrete and fireworks. 60% of all sulfuric acid produced is used to generate phosphoric acid

- Around 40% of all selenium produced goes to glassmaking. 30% of all selenium produced goes to metallurgy, including manganese production. 15% of all selenium produced goes to agriculture. Electronics such as photovoltaic materials claim 10% of all selenium produced. Pigments account for 5% of all selenium produced. Historically, machines such as photocopiers and light meters used one-third of all selenium produced, but this application is in steady decline.[1]
- Tellurium suboxide, a mixture of tellurium and tellurium dioxide, is used in the rewritable data layer of some CD-RW disks and DVD-RW disks. Bismuth telluride is also used in many microelectronic devices, such as photoreceptors. Tellurium is sometimes used as an alternative to sulfur in vulcanized rubber. Cadmium telluride is used as a high-efficiency material in solar panels.[1]

- Some of polonium's applications relate to the element's radioactivity. For instance, polonium is used as an alpha-particle generator for research. Polonium alloyed with beryllium provides an efficient neutron source. Polonium is also used in nuclear batteries. Most polonium is used in antistatic devices.[1][5] Livermorium does not have any uses whatsoever due to its extreme rarity and short half-life.



DNA, an important biological compound containing oxygen