Chlorine is a nonmetal

A general chemistry Libretexts Textmap organized around the textbook Chemistry: The Central Science by Brown, LeMay, Busten, Murphy, and Woodward The line that divides metals from nonmetals in the periodic table crosses the p block diagonally. As a result, the differences between metallic and nonmetallic properties are evident within each group, even though all members of each group have the same valence electron configuration. The p block is the only portion of the periodic table where we encounter the inert-pair effect. Moreover, as with the s-block elements, the chemistry of the lightest member of each group in the p block differs sharply from that of its heavier congeners but is similar to that of the element immediately below and to the right of it in the next group. Thus diagonal similarities in chemistry are seen across the p block. A nonmetal is a chemical element that mostly lacks metallic attributes. Physically, nonmetals tend to be highly volatile (easily vaporized), have low elasticity, and are good insulators of heat and electricity; chemically, they tend to have high ionization energy and electronegativity values, and gain or share electrons when they react with other elements or compounds. Seventeen elements are generally classified as nonmetals; most are gases (hydrogen, helium, nitrogen, oxygen, fluorine, neon, chlorine, argon, krypton, xenon and radon); one is a liquid (bromine); and a few are solids (carbon, phosphorus, sulfur, selenium, and iodine). As you study the periodic trends in properties and the reactivity of the elements in groups 13–18, you will learn how “cobalt blue” glass, rubies, and sapphires are made and why the US military became interested in using boron hydrides as rocket fuels but then abandoned its effort. You will also discover the source of diamonds on Earth, why silicon-based life-forms are likely to exist only in science fiction, and why most compounds with N–N bonds are potentially explosive. You will also learn why phosphorus can cause a painful and lethal condition known as “phossy jaw” and why selenium is used in photocopiers. 22.1: General Concepts: Periodic Trends and ReactionsThe chemistry of the third-period element in a group is most representative of the chemistry of the group because the chemistry of the second-period elements is dominated by their small radii, energetically unavailable d orbitals, and tendency to form π bonds with other atoms.22.2: HydrogenHydrogen can lose an electron to form a proton, gain an electron to form a hydride ion, or form a covalent bond or polar covalent electron-pair bond. The three isotopes of hydrogen—protium (1H or H), deuterium (2H or D), and tritium (3H or T)—have different physical properties. Deuterium and tritium can be used as tracers, substances that enable biochemists to follow the path of a molecule through an organism or a cell.22.3: Group 18: Noble GasesThe noble gases are characterized by their high ionization energies and low electron affinities. Potent oxidants are needed to oxidize the noble gases to form compounds. The noble gases have a closed-shell valence electron configuration. The ionization energies of the noble gases decrease with increasing atomic number. Only highly electronegative elements can form stable compounds (e.g. F and O) with the noble gases in positive oxidation states without being oxidized themselves.22.4: Group 17: The HalogensThe halogens are highly reactive. All halogens have relatively high ionization energies, and the acid strength and oxidizing power of their oxoacids decreases down the group. The halogens are so reactive that none is found in nature as the free element; instead, all but iodine are found as halide salts with the X− ion. Their chemistry is exclusively that of nonmetals. Consistent with periodic trends, ionization energies decrease down the group.22.5: OxygenOxygen is an element that is widely known by the general public because of the large role it plays in sustaining life. Without oxygen, animals would be unable to breathe and would consequently die. Oxygen is not only important to supporting life, but plays an important role in many other chemical reactions. Oxygen is the most common element in the earth's crust and makes up about 20% of the air we breathe. Historically the discovery of oxygen as an element essential for combustion.22.6: The Other Group 16 Elements: S, Se, Te, and PoThe chalcogens have no stable metallic elements. The tendency to catenate, the strength of single bonds, and the reactivity all decrease moving down the group. Because the electronegativity of the chalcogens decreases down the group, so does their tendency to acquire two electrons to form compounds in the −2 oxidation state. The lightest member, oxygen, has the greatest tendency to form multiple bonds with other elements.22.7: NitrogenNitrogen behaves chemically like nonmetals, Nitrogen forms compounds in nine different oxidation states. Nitrogen does not form stable catenated compounds because of repulsions between lone pairs of electrons on adjacent atoms, but it does form multiple bonds with other second-period atoms. Nitrogen reacts with electropositive elements to produce solids that range from covalent to ionic in character.22.8: The Other Group 15 Elements: P, AS, Sb, and BiThe reactivity of the heavier group 15 elements decreases down the group, as does the stability of their catenated compounds. In group 15, nitrogen and phosphorus behave chemically like nonmetals, arsenic and antimony behave like semimetals, and bismuth behaves like a metal. The stability of the +5 oxidation state decreases from phosphorus to bismuth because of the inert-pair effect. Due to their higher electronegativity, the lighter pnicogens form compounds in the −3 oxidation state.22.9: CarbonThe stability of the carbon tetrahalides decreases as the halogen increases in size because of poor orbital overlap and steric crowding. Carbon forms three kinds of carbides with less electronegative elements: ionic carbides, which contain metal cations and C4− (methide) or C22− (acetylide) anions; interstitial carbides, which are characterized by covalent metal–carbon interactions and are among the hardest substances known; and covalent carbides, which have three-dimensional covalent network st22.10: The Other Group 14 Elements: Si, Ge, Sn, and PbThe group 14 elements show the greatest diversity in chemical behavior of any group; covalent bond strengths decease with increasing atomic size, and ionization energies are greater than expected, increasing from C to Pb. Because the covalent bond strength decreases with increasing atomic size and greater-than-expected ionization energies due to an increase in Zeff, the stability of the +2 oxidation state increases from carbon to lead.22.11: BoronElemental boron is a semimetal that is remarkably unreactive. Boron forms unique and intricate structures that contain multicenter bonds, in which a pair of electrons holds together three or more atoms. Elemental boron can be induced to react with many nonmetallic elements to give binary compounds that have a variety of applications.22.E: Chemistry of the Nonmetals (Exercises)These are homework exercises to accompany the Textmap created for "Chemistry: The Central Science" by Brown et al.22.S: Chemistry of the Nonmetals (Summary)This the summary for chapter 22 of the Textmap created for "Chemistry: The Central Science" by Brown et al. Halogens (fluorine, chlorine, bromine, iodine, astatine) are nonmetal elements that are highly electronegative and reactive. Describe the physical and chemical properties of halogens. Key Takeaways Key Points Halogens are nonmetals in group 17 (or VII) of the periodic table. Down the group, atom size increases. As a diatomic molecule, fluorine has the weakest bond due to repulsion between electrons of the small atoms. Due to increased strength of Van der Waals forces down the group, the boiling points of halogens increase. Therefore, the physical state of the elements down the group changes from gaseous fluorine to solid iodine. Due to their high effective nuclear charge, halogens are highly electronegative. Therefore, they are highly reactive and can gain an electron through reaction with other elements. Halogens can be harmful or lethal to biological organisms in sufficient quantities. Key Terms electronegativity: The tendency of an atom to attract electrons to itself. halogens: Group 17 (or VII) in the periodic table consisting of fluorine (F), chlorine (Cl), bromine (Br), iodine (I), and astatine (At). They share similar chemical properties. The halogens are a series of non-metal elements from group 17 of the periodic table (formerly VII). The halogens include fluorine (F), chlorine (Cl), bromine (Br), iodine (I), and astatine (At). The artificially created element 117 (ununseptium) may also be considered a halogen. Physical Properties Atoms get bigger down the group as additional electron shells are filled. When fluorine exists as a diatomic molecule, the F–F bond is unexpectedly weak. This is because fluorine atoms are the smallest of the halogens—the atoms are bonded close together, which leads to repulsion between free electrons in the two fluorine atoms. The boiling points of halogens increase down the group due to the increasing strength of Van der Waals forces as the size and relative atomic mass of the atoms increase. This change manifests itself in a change in the phase of the elements from gas (F2, Cl2) to liquid (Br2), to solid (I2). The halogens are the only periodic table group containing elements in all three familiar states of matter (solid, liquid, and gas) at standard temperature and pressure. Physical States of Halogens: Halogens represents all of the three familiar states of matter: (left to right) chlorine is a gas, bromine is a liquid, and iodine is a solid. Highly reactive fluorine is not included in the picture. Chemical Properties Electronegativity is the ability of an atom to attract electrons or electron density towards itself within a covalent bond. Electronegativity depends upon the attraction between the nucleus and bonding electrons in the outer shell. This, in turn, depends on the balance between the number of protons in the nucleus, the distance between the nucleus and bonding electrons, and the shielding effect of inner electrons. In hydrogen halides (HX, where X is the halogen), the H-X bond gets longer as the halogen atoms get larger. This means the shared electrons are further from the halogen nucleus, which increases the shielding of inner electrons. This means electronegativity decreases down the group. Halogens are highly reactive, and they can be harmful or lethal to biological organisms in sufficient quantities. This reactivity is due to high electronegativity and high effective nuclear charge. Halogens can gain an electron by reacting with atoms of other elements. Fluorine is one of the most reactive elements. It reacts with otherwise inert materials such as glass, and it forms compounds with the heavier noble gases. It is a corrosive and highly toxic gas. Fluorine’s reactivity means that once it does react with something, it bonds so strongly that the resulting molecule is inert and non-reactive. Fluorine can react with glass in the presence of small amounts of water to form silicon tetrafluoride (SiF4). Thus fluorine must be handled with substances like the inert organofluorine compound Teflon. Fluorine reacts vigorously with water to produce oxygen (O2) and hydrogen fluoride: [latex]2 \text{F}_2 (\text{g}) + 2 \text{H}_2\text{O} (\text{l}) \rightarrow \text{O}_2 (\text{g}) + 4 \text{HF} (\text{aq})[/latex] Chlorine has maximum solubility of 7.1 g per kg of water at ambient temperature (21 °C). Dissolved chlorine reacts to form hydrochloric acid (HCl) and hypochlorous acid (HClO), a solution that can be used as a disinfectant or bleach: [latex]\text{Cl}_2 (\text{g}) + \text{H}_2\text{O} (\text{l}) \rightarrow \text{HCl} (\text{aq}) + \text{HClO} (\text{aq})[/latex] Bromine has a solubility of 3.41 g per 100 g of water. It slowly reacts to form hydrogen bromide (HBr) and hypobromous acid (HBrO): [latex]\text{Br}_2 (\text{g}) + \text{H}_2\text{O} (\text{l}) \rightarrow \text{HBr} (\text{aq}) + \text{HBrO} (\text{aq})[/latex] Iodine is minimally soluble in water, with a solubility of 0.03 g per 100 g water. However, iodine will form an aqueous solution in the presence of iodide ion. This occurs with the addition of potassium iodide (KI), forming a triiodide ion. Halogens are highly reactive and can form hydrogen halides, metal halides, organic halides, interhalogens, and polyhalogenated compounds. Discuss halogen compounds and their properties. Key Takeaways Key Points Hydrogen halides are binary compounds of halogens with hydrogen. They are strong hydrohalic acids when dissolved in water, with the exception of HF. All of these acids are dangerous; some are widely used in chemical manufacturing plants. Metal halides are compounds of halogens and metals. They include highly ionic compounds, monomeric covalent compounds, and polymeric covalent compounds. Metal halides can be obtained through direct combination or through neutralization of a basic metal salt with a hydrohalic acid. Interhalogen compounds are formed when halogens react with each other. Some resemble the pure halogens in some respects, but mostly their properties and behaviors are intermediates of those of the two parent halogens. Some properties, however, are found in neither parent halogen. Halogenated compounds, or organic halides, are organic compounds that contain halogen atoms. In the human body, some halogens perform multiple regulatory functions, while others are not essential. Organohalogens are synthesized through the nucleophilic abstraction reaction. Compounds substituted with multiple halogens are known as polyhalogenated compounds. Many of them are very toxic and bioaccumulate in humans, but they have many potential applications. Key Terms interhalogen: A binary compound of two different halogens. polyhalogenated compound: A compound with multiple atoms of halogens. halide: A compound of a halogen and one or more elements. The halogens all form binary compounds with hydrogen, and these compounds are known as the hydrogen halides: hydrogen fluoride (HF), hydrogen chloride (HCl), hydrogen bromide (HBr), hydrogen iodide (HI), and hydrogen astatide (HAt). All of these except HF are strong chemical acids when dissolved in water. However, hydrofluoric acid does have quite destructive properties towards animal tissue, including that of humans. When in aqueous solution, the hydrogen halides are known as hydrohalic acids. The names of these acids are as follows: hydrofluoric acid hydrochloric acid hydrobromic acid hydroiodic acid All of these acids are dangerous and must be handled with great care. Some of these acids are also widely used in chemical manufacturing plants. Hydrogen astatide should also be a strong acid (hydroastatic acid), but it is seldom included in presentations about hydrohalic acids because of the extreme radioactivity of astatine (via alpha decay) and the fact that it readily decomposes into its constituent elements (hydrogen and astatine). Metal Halides The halogens form many compounds with metals. These include highly ionic compounds such as sodium chloride, monomeric covalent compounds such as uranium hexafluoride, and polymeric covalent compounds such as palladium chloride. Metal halides are generally obtained through direct combination or, more commonly, through neutralization of a basic metal salt with a hydrohalic acid. Silver Chloride: Silver chloride is the precipitate formed when silver nitrate solution is added to chloride solution. Interhalogen Compounds The halogens react with each other to form interhalogen compounds. Diatomic interhalogen compounds such as BrF, ICl, and ClF bear resemblance to the pure halogens in some respects. The properties and behavior of a diatomic interhalogen compound tend to be intermediates of those of its parent halogens. Some properties, however, are found in neither parent halogen. For example, Cl2 and I2 are soluble in CCl4, but ICl is not since it is a polar molecule (due to the electronegativity difference between I and Cl). Organic Halides Many synthetic organic compounds, such as plastic polymers, as well as a few natural organic compounds, contain halogen atoms; these are known as halogenated compounds, or organic halides. Chlorine is by far the most abundant of the halogens and is the only one needed (as chloride ions) in relatively large amounts by humans. For example, chloride ions play a key role in brain function by mediating the action of the inhibitory transmitter GABA. They are also used by the body to produce stomach acid. Iodine is needed in trace amounts for the production of thyroid hormones, such as thyroxine. On the other hand, neither fluorine nor bromine is believed to be essential for humans. Organohalogens are also synthesized through the nucleophilic abstraction reaction. Polyhalogenated Compounds Polyhalogenated compounds are industrially created compounds substituted with multiple halogens. Many of them are very toxic and bioaccumulate in humans, but they have many possible applications. Polyhalogenated compounds include the much publicized PCBs, PBDEs, and PFCs, as well as numerous other compounds. Although halogens and their compounds can be toxic, some are essential for the human body’s functioning and are used in everyday products. Discuss the uses of various halogens. Key Takeaways Key Points Fluoride can be found in many everyday products, including toothpaste, vitamin supplements, baby formulas, and even public water. However, overconsumption of fluoride can be fatal. Chlorine accounts for about 0.15 percent of human body weight and plays several important roles in the body’s functioning. Compounds of both chlorine and bromine are used as disinfectants for sterilization. Iodine is essential for the functioning of the body’s thyroid gland. Without iodine, thyroid hormones cannot be produced, which leads to hypothyroidism. Drug candidates that have incorporated halogen atoms are usually more lipophilic and less water-soluble than their analogues, and so have improved penetration through lipid membranes and tissues. Because of this, some halogenated drugs can accumulate in adipose tissue. Polyhalogenated compounds (PHCs) are highly reactive and also bioaccumulate in humans; some of them have toxic and carcinogenic properties. PHCs are used in a vast array of manufactured products and in pest control. Key Terms hypothyroidism: The disease state caused by insufficient production of thyroid hormones by the thyroid gland. polyhalogenated compounds: Compounds with multiple halogen atoms. disinfectant: A substance that kills germs and/or viruses. Despite its toxicity, fluoride can be found in many everyday products, including toothpaste, vitamin supplements, baby formulas, and even public water. Many dental products contain fluoride in order to prevent tooth decay, but overconsumption of fluoride can be fatal. Chlorine Chlorine accounts for about 0.15 percent of human body weight. Chlorine is primarily used in the production of hydrochloric acid, which is secreted from the parietal cells in the stomach and is used in maintaining the acidic environment for pepsin. It plays a vital role in maintaining the proper acid-base balance of body fluids. It is neutralized in the intestine by sodium bicarbonate. Chlorine also reacts with sodium to create sodium chloride, more commonly known as table salt. Both chlorine and bromine are used as disinfectants for drinking water, swimming pools, fresh wounds, spas, dishes, and surfaces. They kill bacteria and other potentially harmful microorganisms through a process known as sterilization. Chlorine and bromine are also used in bleaching. Sodium hypochlorite, which is produced from chlorine, is the active ingredient of most fabric bleaches. Chlorine-derived bleaches are also used in the production of some paper products. Iodine Iodine is an essential mineral for the body. It is used in the thyroid gland but can also be found in breast tissue, salivary glands, and adrenal glands. Without iodine, thyroid hormones cannot be produced, which leads to a condition called hypothyroidism. Without treatment, the thyroid gland will swell and produce a visible goiter. Children with hypothyroidism may develop mental retardation. In women, hypothyroidism can lead to infertility, miscarriages, and breast and ovarian cancer. Thyroid problems have been a common issue for many years, particularly in middle aged women; studies correlate this with the fact that iodine levels in the general population have significantly decreased in recent years. Because of certain health problems, many people have been consuming less salt, which usually contains iodine. In drug discovery, the incorporation of halogen atoms into a lead drug candidate results in analogues that are usually more lipophilic and less water-soluble. Therefore, halogen atoms are used to improve penetration through lipid membranes and tissues. It follows that there is a tendency for some halogenated drugs to accumulate in adipose tissue. Polyhalogenated Compounds Polyhalogenated compounds (PHCs) are of particular interest and importance because halogens are generally highly reactive and bioaccumulate in humans. Halogens are also part of a superset that includes many toxic and carcinogenic industrial chemicals — PBDEs, PCBs, dioxins (PCDDs), and PFCs are all polyhalogenated compounds. DDT DDT (dichlorodiphenyltrichloroethane) is a polyhalogenated pesticide that was banned in the United States in 1972 because of the potential harmful effects on human health. In the second half of World War II, it was used to control malaria and typhus among civilians and troops. The Swiss chemist Paul Hermann Müller was awarded the Nobel Prize in Physiology or Medicine in 1948 “for his discovery of the high efficiency of DDT as a contact poison against several arthropods. ” After harmful environmental impacts of DDT were recognized, it was banned in agricultural use worldwide under the Stockholm Convention, but its limited use in disease vector control continues to this day, though it remains controversial. The US ban on DDT is cited by scientists as a major factor in the comeback of the bald eagle, the national bird of the United States, from near extinction. The Chemical Structure of DDT: DDT (dichlorodiphenyltrichloroethane) is an organochlorine used as an insecticide. It is now banned in the United States because of its potential harmful effects on human health. Key: chlorine atoms: green, carbon atoms: black, hydrogen atoms: white. PHCs are generally immiscible in organic solvents or water but miscible in some hydrocarbons, from which they are often derived. PHCs are used in a vast array of products and industries, such as: Wood treatments Non-stick, waterproof, and fire-resistant coatings Cosmetics Medicine (e.g., cancer therapy, surgery, and medical imaging) Electronic fluids Plastics (e.g., food containers and wrappings) Automobiles Airplanes Clothing and cloth Insulation Adhesives Paints Polyurethane foams Pest control (DDT)