# 8.4 Chemical Families

What makes up a family? Your parents or caregivers, siblings, and yourself make up a family. You may all share certain characteristics, but are you identical? A **chemical family** can be defined as a group of elements that have similar properties and form compounds with similar properties. A chemical family can also be described as a column, or numbered group, in the Periodic Table. A chemical family is a further classification of elements beyond metal, metalloid, or non-metal. In this section, you will explore some chemical families in more detail (Figure 1). 8B *Investigation*

**8B *Investigation***

**Chemical Families and Compounds**

To perform this investigation, turn to page 260.

In this investigation, you will compare elements from Groups 1, 2, 16, and 17.

***LEARNING TIP***

You can use a table to help you organize information for studying. Make a five-column table with the headings: Alkali metals, Alkaline earth metals, Halogens, Noble gases, Hydrogen. Under the appropriate heading, record information in point-form notes to indicate where the chemical family is located in the Periodic Table, its group number, the elements found in each group, and a summary of the properties of each group.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | | | | | | | | | | | | | | | | | He |
| Li | Be | | | | | | | | | | | B | C | N | O | F | Ne |
| Na | Mg | | | | | | | | | | | Al | Si | P | S | Cl | Ar |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr |
| Rb | Sr | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | I | Xe |
| Cs | Ba | La | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn |
| Fr | Ra | Ac | Rf | Db | Sg | Bh | Hs | Mt | Ds | Rg | Uub | Uut | Uuq | Uup | Uuh | Uus | Uuo |
| | | | | Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu |
| | | | | Th | Pa | U | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr |

alkali metals | alkaline earth metals | noble gases | halogens

red = metal | blue = metalloid | green = non-metal

**Figure 1** Chemical families are special groups of elements that have similar properties.

## Alkali Metals

The **alkali metals** are found in the first column (Group 1) of the Periodic Table with the exception of hydrogen. They are lithium, sodium, potassium, rubidium, cesium, and francium. They all have an ion charge of 1+ and are soft, low-density metals that can be cut with a knife (Figure 2). Lithium, sodium, and potassium can float on water. They are not found free in nature because they react with air and water. They are commonly found as ions in salt deposits and in seawater. Sodium and potassium are the sixth and eighth most abundant elements in Earth's crust.

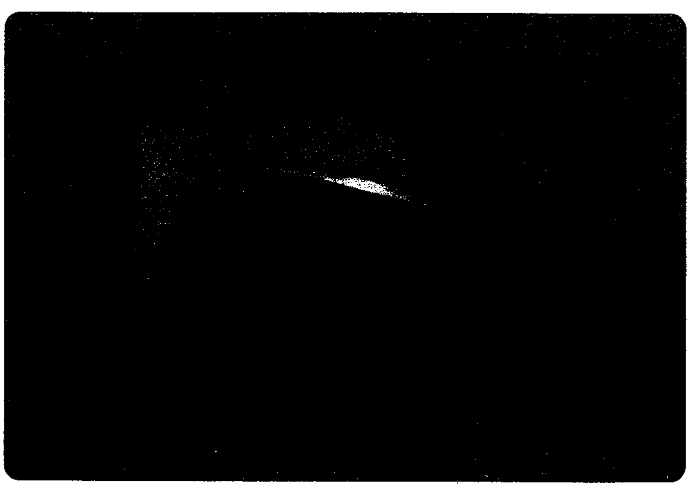

**Figure 2** Sodium metal is soft enough to be cut with a knife.

Refined alkali metals are stored under oil because they react with water to form hydrogen gas and an alkaline (or caustic) solution, from which they get their name. (Alkaline solutions are solutions with more hydroxide ions than hydrogen ions). Sodium, potassium, and the other alkali metals generate enough heat in this reaction to ignite the hydrogen gas produced (Figure 3). Cesium, which sinks in water, produces hydrogen gas so rapidly that it generates a shock wave that can shatter a glass container. Lithium is used in lightweight high-capacity batteries and in grease. Sodium is used in the manufacture of other chemicals. Potassium is a primary ingredient in fertilizers as potassium oxide (potash). GO

If you would like to learn more about alkali metals and other chemical families, go to www.science.nelson.com GO

**Figure 3** Potassium metal reacts with water, producing hydrogen gas. The hydrogen is ignited by the heat released in the reaction.

Table 1 summarizes some of the properties of the alkali metals.

**Table 1** Some Properties of the Alkali Metals

| | |
|---|---|
| **Colour** | silvery-grey |
| **Density** | 0.53 g/cm$^3$ to 1.88 g/cm$^3$ |
| **Melting point** | low; solid at room temperature |
| **Conductivity** | very good for electricity and heat |
| **Reactivity** | very reactive |
| **Ion charge** | 1+ |

**Did You KNOW?**

**Elements in Gemstones**

Emeralds are crystals formed from mineral compounds that contain beryllium, aluminum, and silicon (beryl). If you would like to learn more about elements that make up gemstones, go to

www.science.nelson.com

## Alkaline Earth Metals

The **alkaline earth metals** are found in the second column (Group 2) of the Periodic Table. They are beryllium, magnesium, calcium, strontium, barium, and radium. They all have an ion charge of 2+. They are hard, have low density, and react with air and water. They are primarily found as ions in rock minerals, such as calcium carbonate (also called chalk and limestone), but magnesium is often recovered from seawater (as magnesium chloride). Calcium and magnesium are the fifth and seventh most abundant elements in Earth's crust.

Calcium and barium react violently with water (Figure 4). Barium must be stored under oil. Magnesium burns brightly in air (it is used in flash powder and fireworks). and reacts with carbon dioxide, so magnesium fires cannot be extinguished with $CO_2$ fire extinguishers (Figure 5).

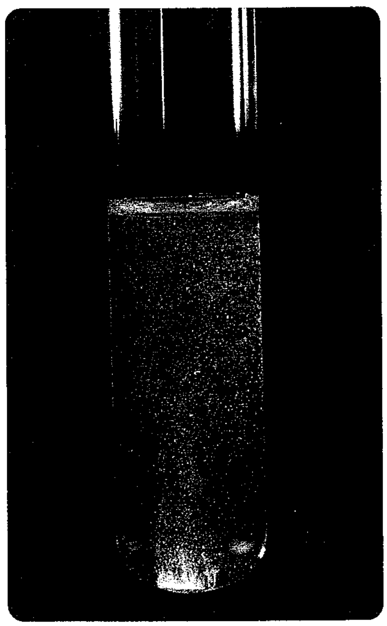

**Figure 4** Calcium metal reacts with water to form bubbles of hydrogen gas.

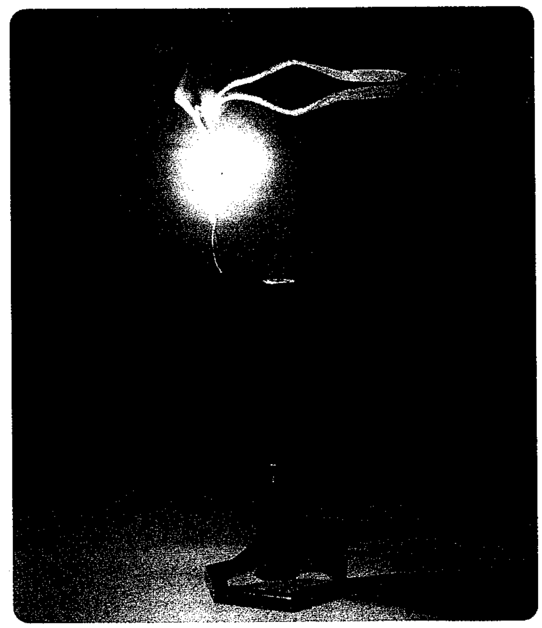

**Figure 5** Magnesium metal burns with a bright white light.

Magnesium and beryllium are important metals for many industrial alloys. Magnesium is often alloyed with aluminum to increase its strength yet maintain its low density. On its own, magnesium has the highest strength-to-weight ratio of any metal. Beryllium and all of its compounds are toxic. Table 2 summarizes some of the properties of the alkaline earth metals.

**Table 2** Some Properties of the Alkaline Earth Metals

| | |
|---|---|
| **Colour** | silvery-white |
| **Density** | 1.55 g/cm$^3$ to 5.00 g/cm$^3$ |
| **Melting point** | higher than alkali metals; solid at room temperature |
| **Conductivity** | good for electricity and heat |
| **Reactivity** | very reactive |
| **Ion charge** | 2+ |

## Halogens

The **halogens** are the second-last column (Group 17) of the Periodic Table. They are fluorine, chlorine, bromine, iodine, and astatine. They are not found free in nature because they react with most other elements, but they are often found in compounds with alkali metals. They all have an ion charge of 1− and they are all toxic in their elemental form.

Fluorine and chlorine are gases at room temperature, bromine is a liquid, and iodine is a solid. Iodine sublimes directly to a gas. All of the halogens have bright colours as gases: chlorine is yellow, bromine is orange, and iodine is purple (Figure 6).

**Did You KNOW?**

**Rare Elements**

Astatine and francium are the two rarest elements on Earth. At any one time, the total amount of astatine on Earth is less than 30 g, and there is less than 20 g of francium. Predicted by Mendeleev to exist, astatine was first synthesized in 1940.

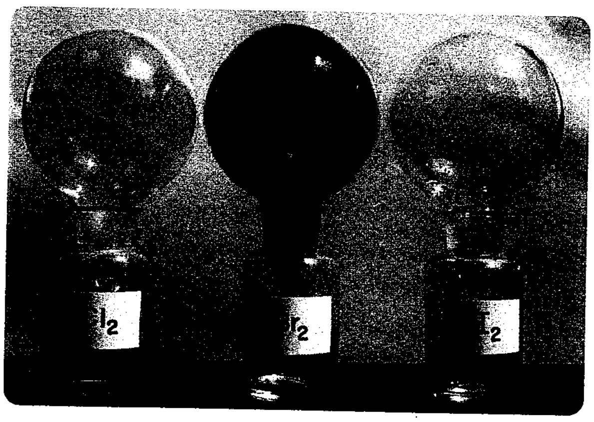

**Figure 6** Chlorine, bromine, and iodine have vivid colours as gases.

Iodine dissolved in alcohol is a common disinfectant used to treat cuts and scrapes. Chlorine is an important industrial chemical, used in plastics (PVC stands for polyvinyl chloride), household bleach, and to purify water supplies. Sodium fluoride and tin(II) fluoride are additives for toothpaste. Table 3 summarizes some of the properties of the halogens.

**Table 3** Some Properties of the Halogens

| | |
|---|---|
| **Colour** | range of bright colours as gases |
| **Density** | 0.0017 g/cm$^3$ to 4.93 g/cm$^3$ |
| **Boiling point** | low |
| **Health effects** | very toxic |
| **Reactivity** | very reactive; reacts with hydrogen to form acids |
| **Ion charge** | 1− |

## Noble Gases

**Noble gases** are the elements in the last column (Group 18) of the Periodic Table. They are helium, neon, argon, krypton, xenon, and radon. They are all non-reactive, and they do not readily form ions. They are tasteless, colourless, odourless, and non-toxic (except for radon).

Helium, being less dense than air, is used as a gas for lifting balloons and blimps (also known as airships). Neon gives off a distinctive red-orange colour when electricity passes through it, and is used for neon signs.

**Did You KNOW?**

**News about Noble Gases**

The noble gases were once called the "inert gases" because they were thought to be completely unreactive. Scientists later discovered, however, that some noble gas can be made to form compounds. This was first accomplished at the University of British Columbia in 1962 by Neil Bartlett when he prepared the compound xenon hexafluoroplatinate ($XePtF_6$). Compounds of most of the noble gases have since been found.

Argon, krypton, and xenon are used to fill incandescent light bulbs. They shield hot tungsten filaments in a light bulb from oxygen (Figure 7). Liquid helium has a temperature of −269 °C and is used to produce extremely low temperatures in a lab or for industry. Radon is denser than air and can accumulate to hazardous levels in the basements of buildings. Table 4 summarizes some properties of the noble gases.

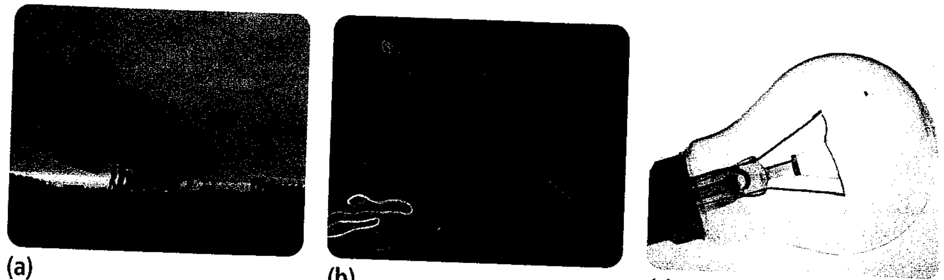

**Figure 7** (a) Helium gas has the lowest density of all gases, and is used to lift balloons and blimps. (b) Neon gas gives off a bright red-orange light when used in electric discharge lights. (c) Noble gases (argon, krypton, and xenon) are used in incandescent light bulbs to prevent the filament from burning off.

**Table 4** Some Properties of the Noble Gases

| | |
|---|---|
| **Colour** | colourless |
| **Density** | 0.00018 g/cm$^3$ to 0.00973 g/cm$^3$ |
| **Boiling point** | very low; for example, helium boils at −269 °C |
| **Reactivity** | generally non-reactive |
| **Ion charge** | 0 |

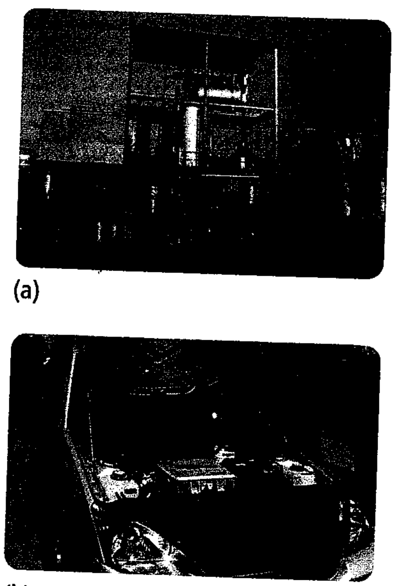

**Figure 8** (a) A hydrogenator is used to add hydrogen to vegetable oils. (b) Automakers are developing cars that use hydrogen as fuel, producing only water as exhaust.

If you want to learn more about fuel cells, go to www.science.nelson.com GO

## Hydrogen

Hydrogen is often referred to as a "family of one." Having only one electron, it can either give up or acquire an electron and can form either positive or negative ions. It has an ion charge of either 1+ or 1−, so it behaves either as a highly reactive metal or as a highly reactive non-metal, depending on the element that it combines with. It is the most common element in the universe and the main component of stars. Because it is so reactive, it is rarely found on Earth in its natural, free state.

Hydrogen is isolated by passing electricity through water. The presence of positive hydrogen ions in water is a property of an acid. It is an important industrial chemical. It is bubbled through liquid vegetable oils to produce hydrogenated oils, or trans fats, which are solid at room temperature (Figure 8(a)). Hydrogen is used as a fuel to burn or react in fuel cells, and is used in the manufacture of many products and chemicals (Figure 8(b)). GO

Table 5 summarizes some of the properties of hydrogen.

**Table 5** Some Properties of Hydrogen

| | |
|---|---|
| **Colour** | colourless |
| **Density** | 0.000090 g/cm$^3$ (lowest of all elements) |
| **Boiling point** | extremely low |
| **Reactivity** | very reactive; burns in air; forms a diatomic molecule, $H_2$; combines with many negative ions to form acids |
| **Ion charge** | 1+ or 1− |

## Predicting Formulas Using Chemical Families

If you know about chemical families and understand how the Periodic Table organizes elements, you can predict the formulas of compounds more easily. For example, all the elements in Group 1 of the Periodic Table (alkali metals and hydrogen) have the same ion charge. So, if sodium reacts 1:1 with chlorine (a Group 17 element) to form sodium chloride (NaCl), then each of the Group 1 elements will do the same, for example (KCl and LiCl). You can also predict that sodium and other Group 1 elements will react in a 1:1 ratio with any element in Group 17, (for example, NaF and KF).

Similarly, if magnesium (a Group 2 element) and bromine (a Group 17 element) react in a 1:2 ratio to form magnesium bromide, $MgBr_2$, then magnesium iodide should have a similar formula, $MgI_2$. What would be the formula of magnesium fluoride? It is $MgF_2$. What would be the formula of calcium bromide? It is $CaBr_2$. You will find other family relationships in Table 6, which shows some of the compounds formed by different members of the same chemical family. Note the similarities in the formulas.

**Table 6** Compounds

| Known compound formula | Predictions from periodic table |
|---|---|
| KCl | KI, KF, KBr,<br>LiCl, NaCl, RbCl, CsCl |
| $SrBr_2$ | $SrF_2$, $SrCl_2$, $SrI_2$,<br>$BeBr_2$, $MgBr_2$, $CaBr_2$, $BaBr_2$ |
| $AlCl_3$ | $AlF_3$, $AlBr_3$, $AlI_3$,<br>$BCl_3$, $GaCl_3$, $InCl_3$, $TlCl_3$ |
| $Mg_3N_2$ | $Mg_3P_2$, $Mg_3As_2$,<br>$Be_3N_2$, $Ca_3N_2$, $Sr_3N_2$, $Ba_3N_2$ |

The properties of compounds that are formed from different elements in a chemical family have similar properties. The physical and chemical properties of strontium and calcium are similar, so your body will use strontium compounds like it uses calcium compounds—to build bone tissue. Sodium chloride and sodium iodide look and taste very much the same. All sodium compounds and all potassium compounds are soluble in water. GO

**Did You KNOW**

**Radium**

Radium is very dangerous if ingested because the body will use radium the same way it uses radium's family member, calcium—to build bone cells. The radioactivity of radium atoms will cause damage to the surrounding cells, particularly the bone marrow. To learn more about this and the use of radioactive strontium to treat bone cancer, go to

www.science.nelson.com GO

To find more uses of elements, go to

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