Explainer: Uses of Period 4 Metals

In this explainer, we will learn how to list and explain uses for the period 4 d-block metals.

Period 4 metals are an incredibly interesting and important group of elements that make up around 6.3% of the elements in the sea and in Earth's continental crust. Period 4 elements are very strong and vital to the chemical industry.

The percentage abundance of chemical elements in Earth's continental crust and in the sea can be seen in the following table.

Element	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Percentage Abundance	0.0022	0.565	0.0120	0.0102	0.0950	5.63	0.0025	0.0084	0.0060	0.0070

Some period four elements are very rare, while others are common. But every group 4 element has at least one important use. Scandium is very rare and used in aircraft, while iron is the 4th most abundant element in Earth's crust and found all around us as part of the alloy steel. Group 4 metals are truly fascinating, and we shall look at each metal in turn, describing some of the well-known, important, or interesting uses of these elements.

Example 1: Recalling Which Period 4 d-Block Metal Is the Most Abundant in Earth's Crust

Which of the period 4 d-block metals is the most abundant in Earth's crust?

A. Zinc

B. Iron

C. Nickel

D. Titanium

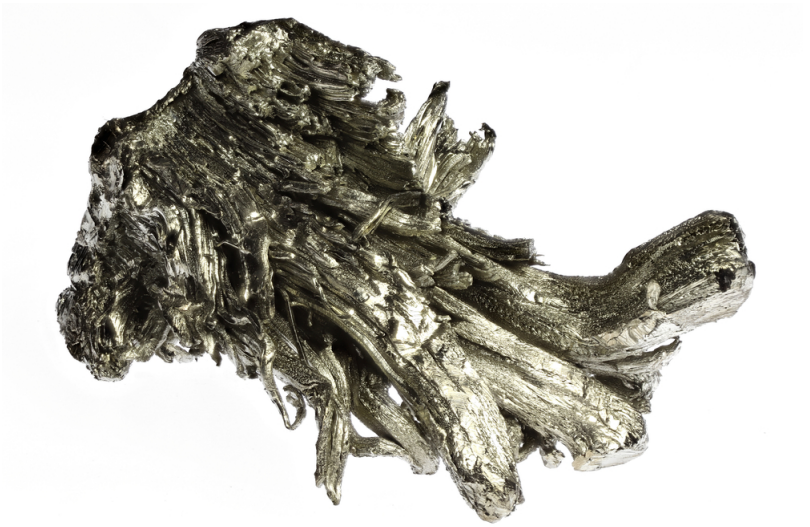
E. Copper

Answer

Iron is the 4th most abundant element in Earth's continental crust and in the sea after oxygen, silicon, and aluminum. Iron makes up 5.63% of Earth's crust, whereas zinc is 0.0070%, nickel is 0.0084%,

titanium is 0.565%, and copper is 0.0060% of Earth's crust. We can use this information to determine that B is the correct answer.

The first period 4 d-block element we will examine is scandium, a silvery white metal, shown below, that was first discovered in Scandinavia in 1879.



We can make metals stronger by mixing them with other metals to create alloys. Small amounts of scandium ($\sim$ 2%) can be mixed with large amounts of aluminum to make an alloy that has high mechanical strength, high ductility, and improved corrosion resistance. These metal alloys are light and very hard.

Aluminum–scandium alloys were first developed by the Soviet Union during the cold war era, where they were used in the manufacture of missiles and MiG fighter jets. Although these scandium alloys could be used in other industries due to their advantageous properties, the relative scarcity of this metal makes use outside of the aeronautical industry economically unviable.

Scandium compounds such as scandium triiodide can be added to mercury-vapor lamps to produce light that is similar to sunlight in color and intensity, making it useful when filming scenes for film and television.

Example 2: Identifying an Application of Scandium Metal

Which of the following is one of the applications of scandium?

A. Manufacturing of artificial joints

B. Leather tanning

C. Manufacturing of MiG fighter jets

D. High-power magnets

E. Manufacturing of car springs

Answer

Scandium is in group 13 of the periodic table. It is frequently used in the production of alloys and was used in the manufacture of missiles and MiG fighters when alloyed with aluminum.

Manufacturing artificial joints and car springs often involves the use of the metal titanium due to its high strength. Leather turning often involves the use of chromium salts, and high-power magnets are often made in part from either nickel or cobalt. As such, we can see that the correct answer is C: manufacturing of MiG fighter jets.

Next to scandium, we find the period 4 d-block element titanium, shown in the image below. Titanium is a light metal, but it has very high strength and is resistant to corrosion.

One of the primary uses of titanium is in the production of titanium–aluminum alloys. These alloys are used heavily in the production of aircraft, armor plating, and even spacecraft! When titanium is alloyed with aluminum, vanadium, and other elements, the alloys produced have high tensile strength but are also relatively lightweight and can withstand high temperatures without being damaged.

An everyday use of titanium is in the production of titanium oxide-based sunblock. Titanium dioxide makes an excellent compound for sunblock, as nanoparticles of the compound can be produced, allowing sunblock to appear invisible after it is applied to the skin. It also has a very good record for not causing irritation to sensitive skin. Most importantly for a sunblock, TiO_2 is very effective at blocking shortwave ultraviolet A (UVA) and ultraviolet B (UVB) rays coming from the Sun.

Although there are many uses of titanium, the final one we will consider is the use of titanium in the construction of dental implants. The benefits of using titanium is that it is corrosion resistant but also unreactive; therefore, it is nontoxic. Titanium metal and its alloys are used in dentistry due to

their light weight and strength, making them cheap and effective materials to use in the production of dental implants. The photograph below shows a dental teaching model with a titanium metal tooth-implant screw.

The third period 4 element in the d block of the periodic table is vanadium, which occurs naturally in around 65 different minerals and fossil fuel deposits. A high-purity vanadium disk can be seen in the following picture.

Vanadium is used as an additive metal in some types of steel. Steels that contain metals such as vanadium and chromium are more hardenable.

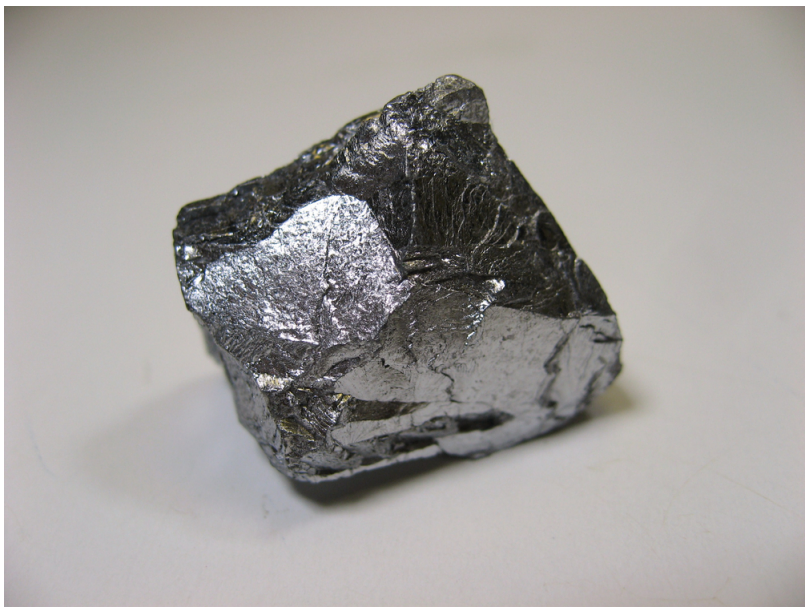
Definition: Hardenable

In metallurgy, a hardenable alloy is an alloy that can have its hardness increased to become more highly resistant to deformation.

Steels containing vanadium and chromium are also incredibly resistant to corrosion, making them useful in the production of springs for car suspension.

There are many important vanadium compounds, such as the vanadium oxides used in the ceramics and glass industries. One oxide, vanadium pentoxide (V_2O_5), is used as a catalyst in the contact process where it oxidizes sulfur dioxide to sulfur trioxide. Vanadium pentoxide is also used as a catalyst in the manufacture of strong magnetic conductors and as a dye used by the ceramics and glass industries.

Chromium is a period 4 d-block element in group 6 that is perhaps most well known for its decorative uses because it can be highly polished and resists corrosion. Chromium metal crystals and a cube of solid chromium metal can be seen in the following image.



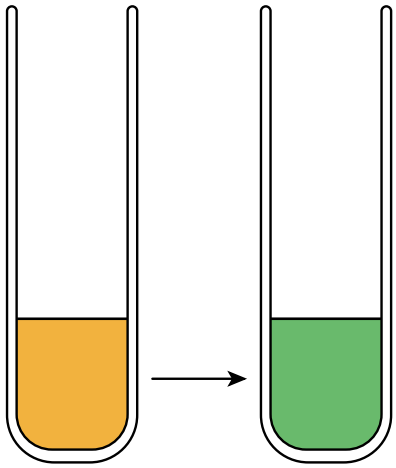
Chromium resists corrosion because of an oxide layer that forms on its surface when it comes into contact with oxygen in the air. Chromium's incredibly shiny and aesthetically pleasing finish is due to the fact that the metallic structure of chromium metal is incredibly uniform and absorbs and reemits light without being scattered.

Chromium also forms an alloy with iron known as ferrochrome. Ferrochrome is 50%–70% chromium by weight, and it is used in the production of stainless steel.

Chromium compounds have many uses. Chromium salts such as chrome alum ($KCr(SO_4)_2$) and chromium(III) sulfate are used in the process of leather tanning. During the tanning process, chromium creates cross-links between the collagen fibers in the animal hide. Although the compounds used for tanning do not include chromium in its toxic +6 oxidation state, there is still sustained interest in the development of tanning methods that do not rely on chromium salts and risk the consequential absorption of chromium through the skin.

Other common chromium compounds include chromium(III) oxide (Cr_2O_3), which is used in the manufacture of dyes. Potassium dichromate ($K_2Cr_2O_7$) is a common organic oxidizing agent

that is frequently used to oxidize primary alcohols to carboxylic acids. This oxidation reaction is accompanied by a well-known color change, as the orange-yellow potassium dichromate solution turns a green color. This color change corresponds to the chromium ions being reduced to the 3+ state.



Example 3: Identifying a Period 4 Metal from Its Applications

Which of the following period 4 metals is commonly used in alloys with iron as a decorative plating on car headlamps and has compounds that are used in the tanning of leather?

A. Zinc

B. Scandium

C. Cobalt

D. Copper

E. Chromium

Answer

In this question, we are asked to identify which period 4 metal is involved in a variety of different uses. The first use involves alloying with iron. There are several metals, such as chromium and cobalt, that are used in common iron alloys.

However, of those two metals, chromium is also used in the metal plating of car headlamps. In addition, different chromium salts are used to cross-link the collagen fibers when tanning leather. Therefore, the correct answer is E: chromium.

The fifth period 4 d-block element we will examine is manganese, which was first isolated by the Swedish chemist Johan Gottlieb Gahn in 1774. Electrolytically refined manganese chips and a cube of manganese metal can be seen in the photograph below.

Perhaps manganese's most important use is in the production of steel where it is considered to be of critical importance, as there is no satisfactory substitute for manganese in many applications of metallurgy. When alloyed with iron, ferromanganese is formed. Ferromanganese is used as an additive in many different types of steel. On its own, manganese is a very brittle material, so it is more useful as an alloy.

Manganese in the form of manganese dioxide (MnO_2) is used in alkaline batteries, allowing for the production of fairly small primary cells with a high performance. Current research is exploring new applications by introducing manganese into lithium ion cells.

Manganese compounds may well be familiar to students in high school, with substances such as potassium permanganate ($KMnO_4$) being used as a common oxidizing agent. Potassium permanganate can be used as an antiseptic, and crystals of $KMnO_4$, with its characteristic deep purple color, can be seen dissolving into a beaker of water in the following picture.

Another well-known reaction is the production of oxygen gas from the catalytic decomposition of hydrogen peroxide by manganese dioxide (MnO_2):

$$2\,H_2O_2(aq) \xrightarrow{MnO_2} 2\,H_2O(l) + O_2(g)$$

Other useful compounds of manganese include manganese(II) sulfate, which has many uses such as in the production of fungicides, antiseptics, fertilizers, glazes, varnish, and ceramics.

The final use to consider for manganese is that it can be alloyed with aluminum to create a corrosion-resistant alloy that is used in the manufacture of soft drink cans.

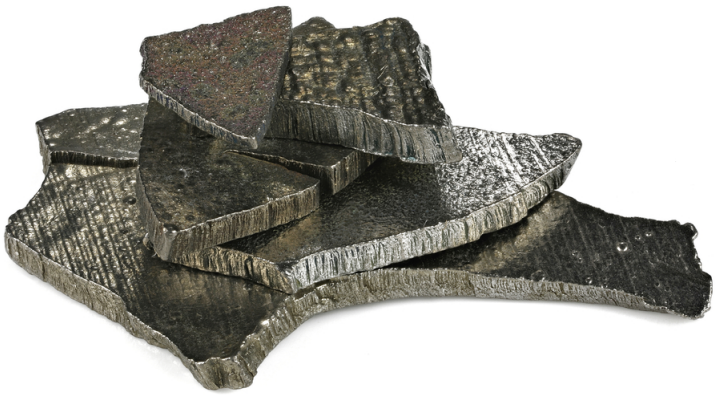
One of the most well-known period 4 elements is iron, which humans have been isolating from its ore for millennia.

It is well known that iron is the key ingredient of steel, and without steel, many everyday materials and items would not be possible to produce. Reinforced concrete, electricity pylons, guns, knives, and surgical tools all rely on different iron-based alloys and materials.

However, iron is also an important catalyst. The ore magnetite is the primary source of the catalytic iron used in the Haber–Bosch process, which manufactures ammonia on an industrial scale. Iron is also a catalyst in the Fischer–Tropsch method of converting water gas to liquid fuel.

Iron is also a magnetic material exhibiting ferromagnetic properties, which means that it can be magnetized by an external magnetic field and will remain a permanent magnet afterward.

In group 9 and period 4 of the periodic table, we find the element cobalt. Cobalt is a hard and lustrous metal that is often produced as a byproduct of copper and nickel mining.



Similar to iron, cobalt too can be magnetized, resulting in the production of some incredibly strong magnets such as samarium–cobalt (SmCo) magnets, which are extremely resistant to demagnetization. Cobalt and its alloys are also used in hard disk drives and MRI machines as well as in the dry batteries of modern cars. The scarcity of cobalt can cause the price of this element to fluctuate, making it a less desirable choice for some industries.

Cobalt has 12 radioactive isotopes. Cobalt-60 is a synthetically produced radioactive isotope of cobalt that has a half-life of around five years. The Cobalt-60 isotope produces gamma rays that have high penetrating powers, enabling its use in the medical profession to sterilize equipment and diagnose and treat tumors. Food irradiation is another application of this isotope. Food irradiation extends shelf life by destroying microorganisms that would otherwise spoil the food. Finally, cobalt-60 is used to assess the quality of industrial products by detecting cracks in pipes and in welded connections.

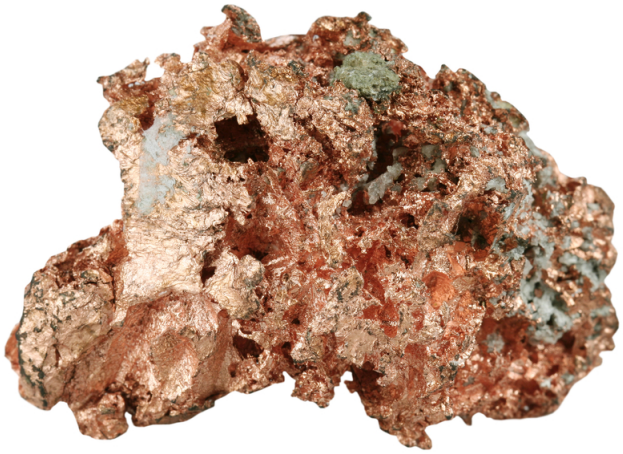
The eighth element in the series of period 4 metals is nickel. Nickel is a hard and ductile metal that forms a protective oxide layer when exposed to the oxygen in air.

Many household rechargeable batteries are made with nickel. Nickel–cadmium batteries were invented over a hundred years ago in 1899 and are still a very popular form of rechargeable batteries today. Nickel is used to plate other metals, protecting them from corrosion and giving them a beautiful appearance.

Nickel metal is also used as a catalyst in the hydrogenation of vegetable oils, an important industrial process. The catalyst consists of finely divided nickel known as Raney nickel, named after Murray Raney (the American engineer who developed the catalyst in 1926).

Like many of the other period 4 metals, nickel can be alloyed with other metals. Although there are many examples, one of note is the alloy formed between nickel, iron, and chromium, which has very high heat and corrosion resistance and is used in the steam turbines of power plants and electric furnaces.

The penultimate period 4 d-block element is copper, a well-known metal used around the world in electrical wiring because it is a good conductor of electricity. The distinct color of copper metal is shown in the image below.



Copper is part of two very well-known alloys: brass and bronze. Bronze is an alloy that has been known to humans for millennia and has been used to construct sculptures, make musical instruments, and protect boats at sea due to its resistance to corrosion. There are many different bronze alloys, but in most cases, bronze is an alloy of copper and tin.

Copper metal is also important in teaching organic chemistry due to its inclusion in Fehling's solution. The blue Fehling's solution is used in chemistry to differentiate between ketone and aldehyde functional groups, and it is used in biology to differentiate between water-soluble carbohydrates and ketone-containing compounds. Fehling's solution turns an orange-red with a positive test.

Copper compounds also have many important uses in our society. Copper sulfate can be used as an insecticide and as a fungicide, and it can also be used as an electrolyte in the printing trade and in the metal industry.

The final period 4 d-block element we will examine is zinc, which is considered to be a post-transition metal and is the 24th most abundant element in Earth's crust.

Zinc is frequently used in batteries, although it is not necessarily used in manufacturing the best performing of batteries. Zinc–carbon batteries are cheap to produce and last for a long time in devices that do not drain a lot of power such as television remote controls.

Zinc metal is also used for galvanization and in the sacrificial protection of other metals when preventing corrosion. Zinc compounds such as zinc oxide (ZnO) and zinc sulfide (ZnS) are used in the manufacture of illuminating paint and X-ray screens.

A kilogram of iron may cost less than a dollar; however, a kilogram of scandium could cost over $3 000. With such large difference in price, the fact that these prices fluctuate, and the fact that certain metals are only found in certain countries, the economic influence and the effect of period 4 metals on industries are clear to see.

From fighter jets to sunblock and from leather tanning to food irradiation, period 4 d-block metals are a fascinating and essential collection of metals that make modern life as we know it possible.

Let us summarize what has been learned in this explainer.

Key Points

- There are 10 period 4 d-block metals, from scandium in group 3 to zinc in group 12.
- Period 4 d-block metals have a wide range of uses, making them incredibly important to society and, consequently, the economy.

- Many of the metals are used to some degree in the production of different alloys to create materials with desirable physical properties.
- Metals such as vanadium, nickel, and iron are useful as catalysts.
- Elements such as nickel, manganese, and zinc are useful in the production of batteries.
- Many of these metals have compounds that are also useful in laboratory chemistry, such as potassium permanganate and copper sulfate.