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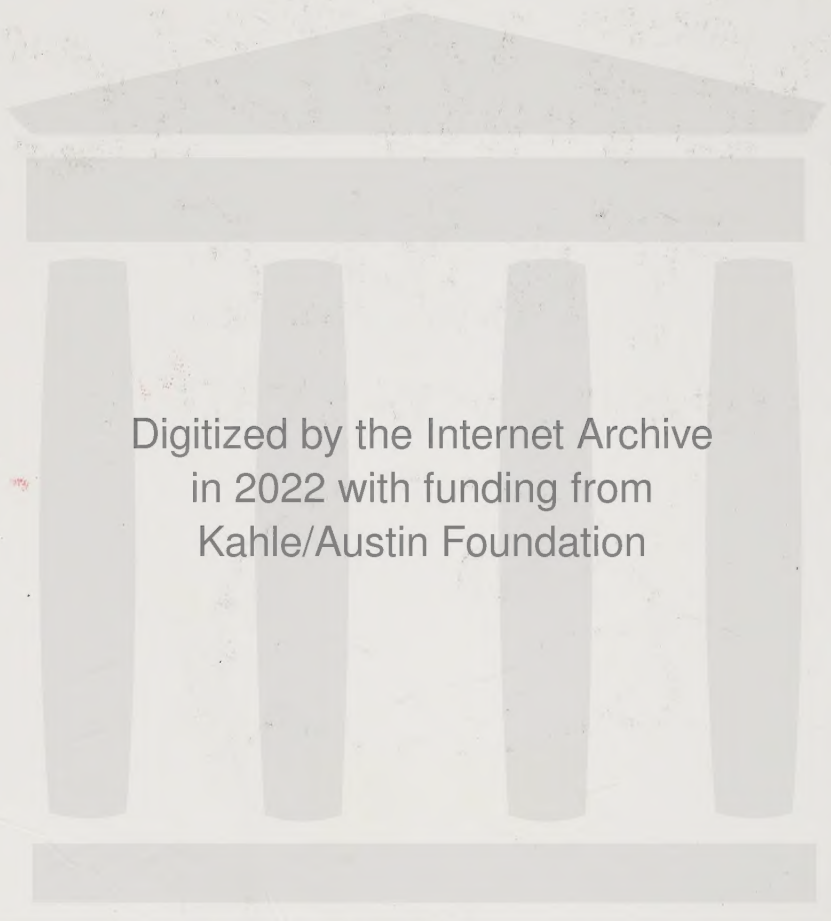
# THE COMPLETE PERIODIC TABLE

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# THE PERIODIC TABLE

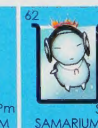
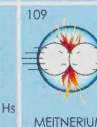
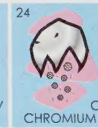
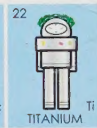
ELEMENTS WITH STYLE!

WITHDRAWN



KINGFISHER  
NEW YORK





# THE PERIODIC TABLE

ELEMENTS WITH STYLE!



KINGFISHER  
NEW YORK



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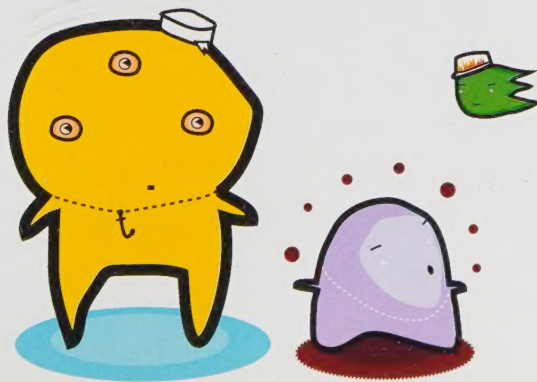
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# The Periodic Table



## Introduction

Everything in the world is made of elements—substances that cannot be broken down or made into anything simpler by chemical reactions. Each element has its own unique personality. Many, such as gold, silver, and lead, have been known for millenia. Others, such as livermorium, have been created in high-tech labs, only as recently as 2000, and chemists are busy making more.

The periodic table was the brainchild of Siberian superchemist Dmitri Mendeleev. In 1869, he arranged the known elements into groups (columns) and periods (rows), leaving gaps in his table for chemical elements that were still undiscovered at the time. Today the gaps have been filled, and there are a total of 118 known elements, but there may be others that are yet undiscovered. The vertical groups of the table make up “families”—all closely related and liking the same sorts of chemical shenanigans. In this book you’ll meet every one of 118 characters, from the lightest to the heaviest, and including all the breakaways and mavericks that like to do things their own way. . .



101

Md



Mendelevium (named after Mendeleev)

# 1 Hydrogen



- ☼ Symbol: H
- ☼ Atomic number: 1
- ☼ Atomic weight: 1.008
- ☼ Color: None
- ☼ Standard state: Gas at 25°C (77°F)
- ☼ Classification: Nonmetallic

I may be undersized, but don't underestimate me. I'm a petite package who packs a punch, and I have a fiery character to boot—always remember that I'm *numero uno*! I am the simplest and lightest of all the elements, the most abundant in the Universe, and the source of everything in it—from matter and energy to life. I'm what powers nuclear fusion in the stars, and I'm the building block for all of the other elements of the periodic table.

On Earth, I exist as a gas consisting of a pair of hydrogen atoms ( $H_2$ ). Things always happen with a bang when I'm around. I'm extraordinarily flammable. I was once used to fill airships, until a few fatal explosions ended my career. In the future, I am set to become important in fuel cells—a clean and efficient way of generating electricity.

Date of discovery: 1766

- Density 0.082 g/l
- Melting point  $-259.14^{\circ}\text{C}$  ( $-434.45^{\circ}\text{F}$ )
- Boiling point  $-252.87^{\circ}\text{C}$  ( $-423.17^{\circ}\text{F}$ )



H





# CHAPTER 1

## The Alkali Metals

## Group 1



A rowdy bunch of rebels, these elements have a reputation for extremely reactive behavior. Chemically too feisty to be found unchanged in nature, this group is closer and more alike than any other group of the periodic table. All members are low-density, soft metals. When added to water, they turn it alkaline. Their dangerous desperation to lose their outer electron increases with their atomic number, and as soon as they come into contact with almost anything (including air), a violently explosive reaction follows. . .



# Lithium

## ■ The Alkali Metals

- ✧ Symbol: Li
- ✧ Atomic number: 3
- ✧ Atomic weight: 6.941
- ✧ Color: Silvery gray/white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

The lightest of all metals on the periodic table and the first, I am a real soft touch. You can easily slice me with a knife, but when I'm combined with other metals like aluminum, I make very strong (and light) alloys. These qualities make me popular with the aerospace industry.

I am generally a useful and very helpful character. You can find me acting as the positive half of many batteries and as part of high-performance, industrial lubricants.

As lithium chloride (me plus chlorine), I'm remarkably good at absorbing large amounts of water. Taken as lithium carbonate (me, oxygen, and carbon), I help restore damaged personalities—calming and relieving sufferers of mental illnesses such as bipolar disorder.

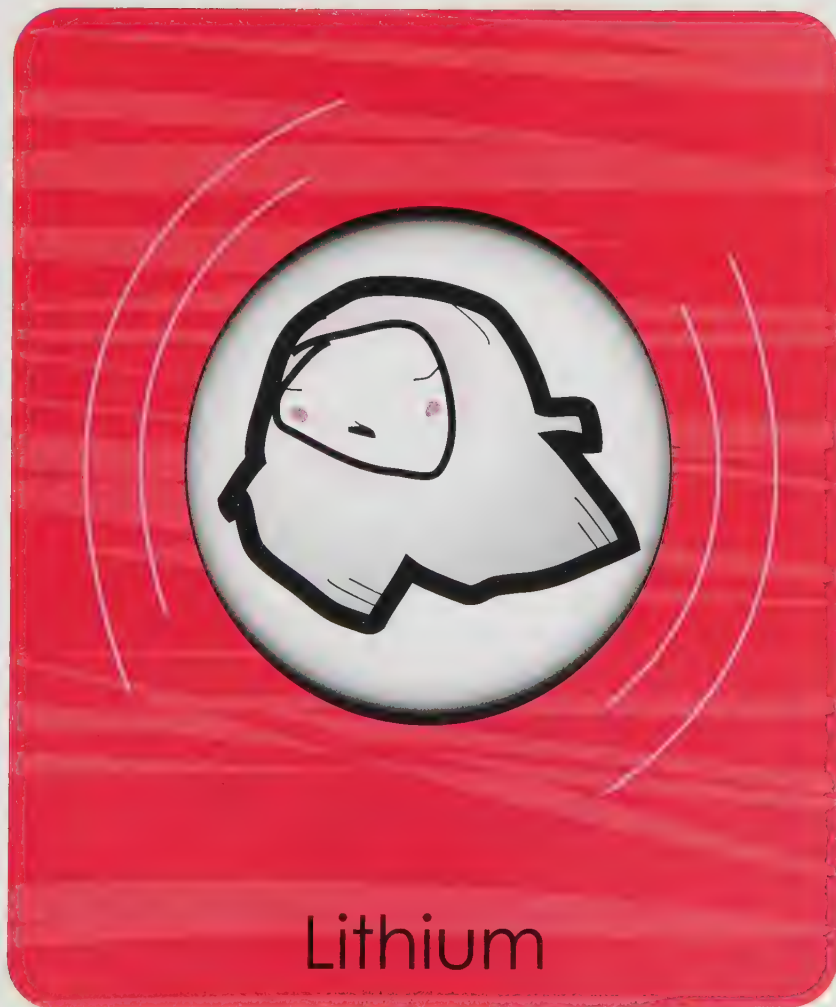
Date of discovery: 1817

- Density 0.535 g/cm<sup>3</sup>
- Melting point 180.54°C (356.97°F)
- Boiling point 1,342°C (2,448°F)





Li



# 11 Sodium

## ■ The Alkali Metals

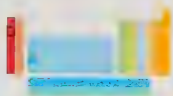
- ✧ Symbol: Na
- ✧ Atomic number: 11
- ✧ Atomic weight: 22.990
- ✧ Color: Gray/white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

I'm a complete live wire—high-strung and volatile—but I get along well with everyone and make strong, long-lasting friendships. I'm a gray-colored metal that's soft enough to be cut with a knife. I'm really reactive—you need to store me under oil to stop me from chemically reacting with the oxygen in air, and I'll explode into flames on contact with water!

I form lots of common compounds, like sodium chloride (salt) and sodium carbonate (dishwashing soap), which are all solid and very stable owing to their strong bonds. My ions (negative particles) are very soluble and are the reason why the sea is salty. I give streetlights their orange glow, and I am used in nuclear reactors as a coolant because I conduct heat really well.

Date of discovery: 1807

- Density 0.968 g/cm<sup>3</sup>
- Melting point 97.72°C (207.9°F)
- Boiling point 883°C (1,621°F)



Na





# 19 Potassium

## ■ The Alkali Metals

✧ Symbol: K

✧ Atomic number: 19

✧ Atomic weight: 39.098

✧ Color: Silver

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I am sodium's twin. I am soft and react with air, so storing me under oil is essential. This small precaution keeps me isolated from contact with air or water. My ions can be easily detected in any substance since they give off a bright lilac flame. Just as dazzling is my explosive reaction with water, which is even stronger than that of sodium.

Everyone knows that I can be found in bananas, but I bet you didn't know that I am central to many processes in your body. Most vitally, I aid the function of the nerves, allowing the brain to transmit information to the muscles. But too much of me in the body can lead to a heart attack, and this is my darker side—in the U.S., potassium chloride is used in the lethal injections that kill Death Row prisoners.

● Date of discovery: 1807

● Density 0.856 g/cm<sup>3</sup>

● Melting point 63.38°C (146.08°F)

● Boiling point 759°C (1,398°F)



# 37 Rubidium

## ■ The Alkali Metals

- ✧ Symbol: Rb
- ✧ Atomic number: 37
- ✧ Atomic weight: 85.468
- ✧ Color: Silvery
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Another big softy in a group of squishy metals, I'm barely solid at room temperature. I'm a shy and elusive type and like to pretend to be one of the other Group 1 elements. In fact, I can disguise myself so well, it can be hard to tell us apart. Like the rest of the gang, I'm superreactive. I go off with a very big bang on contact with air or water.

I'm scarce and hard to find, but even so, I'm the element of choice when it comes to low-power lasers. Printers, telecoms networks using fiber-optic cable, and store barcode readers all use me in their diode laser systems. (Lasers take on a characteristic red-pink color.) I'm also used in compact, superaccurate atomic clocks. My tricky rarity makes me very expensive. Keep your eyes peeled for me in medicines of the future. . .

■ Date of discovery: 1861

- Density 1.532 g/cm<sup>3</sup>
- Melting point 39.31°C (102.76°F)
- Boiling point 688°C (1,270°F)





Rb



Rubidium



# 55 Cesium

## ■ The Alkali Metals

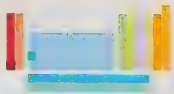
- ★ Symbol: Cs
- ★ Atomic number: 55
- ★ Atomic weight: 132.91
- ★ Color: Golden tinge
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic

Soft and golden, I'm way more exciting than gold. When provoked, I give off a sky-blue light. Of my Group 1 gang, I have the fiercest reaction to water. I keep the beat in atomic clocks—accurate to one second every several hundred thousand years! My nasty radioactive isotope, cesium-137, was a major pollutant after the 1986 Chernobyl nuclear disaster in the former U.S.S.R.



■ **Date of discovery: 1860**

- Cs
- Density 1.879 g/cm<sup>3</sup>
  - Melting point 28.44°C (83.19°F)
  - Boiling point 671°C (1,240°F)



# Francium 87

The Alkali Metals ■

- ★ Symbol: Fr
- ★ Atomic number: 87
- ★ Atomic weight: 223.02
- ★ Color: Unknown
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



I'm an unstable little critter and I'm very radioactive. With a half-life of only 22 minutes, I don't hang around for long. This makes me extremely rare—no weighable sample has ever existed. That's why my color remains something of a mystery. I'm named after the country; my discoverer, Marguerite Perey, was the first woman to be admitted to the French Academy of Sciences.



Date of discovery: 1939

- Density 2.91 g/cm<sup>3</sup>
- Melting point 30°C (86°F)
- Boiling point 598°C (1,108°F)

Fr

# CHAPTER 2

## The Alkaline Earth Metals

## Group 2



The “alkaline earths” were once thought to be totally harmless and boring, because they were always found tightly bonded to oxygen. However, once released from these stable compounds, they began to act in the same unruly fashion as their next-door neighbors, the Group 1 family. Another gang of soft metals, these guys react easily and burn fiercely, getting meaner toward the base of the group. All are eager to lose their outer electrons, but this happens less easily than it does for the alkali metals, so they are a little less active.



4



Be

BERYLLIUM

12



Mg

MAGNESIUM

20



Ca

CALCIUM

38



Sr

STRONTIUM

56



Ba

BARIUM

88



Ra

RADIUM

# 4 Beryllium

## The Alkaline Earth Metals

- ✧ Symbol: Be
- ✧ Atomic number: 4
- ✧ Atomic weight: 9.0122
- ✧ Color: Silvery
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Lucky for you, I am shy and secretive and don't get out much. A small amount of me in your body can give you berylliosis, a disease that inflames the lungs and is linked to lung cancer. As a metal, I am soft and silvery, and I'm used mostly in metal alloys, in league with other metals. I make an excellent electrical conductor, and I'm very flexible, too. Because I am so superlight, I also get used in the manufacture of airplanes.

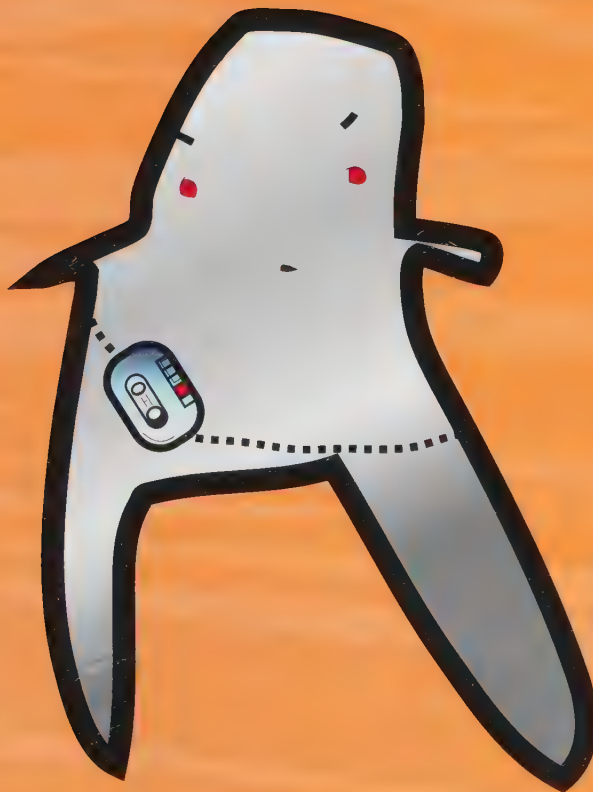
I'm often dug out of the ground as silicates—compounds that I form with silicon and other elements—the most beautiful of which is an emerald. My proudest moment came in 1932 when James Chadwick bombarded me with alpha particles and discovered the neutron. The neutrons that I produce now play a leading role in nuclear chemistry.

Date of discovery: 1797

- Density 1.848 g/cm<sup>3</sup>
- Melting point 1,287°C (2,349°F)
- Boiling point 2,469°C (4,476°F)



Be



Beryllium



# 12 Magnesium

## ■ The Alkaline Earth Metals

- ✧ Symbol: Mg
- ✧ Atomic number: 12
- ✧ Atomic weight: 24.305
- ✧ Color: Silver-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

I'm happy to mix in any social gathering of the elements, making friends with anyone, even moody hydrogen. I'm sparky, and I always cause a reaction!

I'm a smart aleck, too—I can speed up your body processes and make you rush to the bathroom! The laxatives Epsom salts and milk of magnesia are both made using my salts, which also give a bitter taste to food and can leave a bad taste in your mouth.

I am a silver-white metal and burn with incredible intensity and a bright white light. My splendiferous powers of combustion are used in flashbulbs, distress flares, fireworks, and incendiary bombs. Strong and light, I help make bike frames, car parts, and aircraft engines.

Date of discovery: 1755

- Density 1.738 g/cm<sup>3</sup>
- Melting point 650°C (1,202°F)
- Boiling point 1,090°C (1,994°F)





Mg



Magnesium



# 20 Calcium

## ● The Alkaline Earth Metals

- |                         |                                        |
|-------------------------|----------------------------------------|
| ✱ Symbol: Ca            | ✱ Color: Silvery                       |
| ✱ Atomic number: 20     | ✱ Standard state: Solid at 25°C (77°F) |
| ✱ Atomic weight: 40.078 | ✱ Classification: Metallic             |

They call me “The Scaffolder” because I make up a large portion of the parts that hold you together—your skeleton and teeth. I’m needed in large amounts as you grow, to build the calcium phosphate of your bones, and as you get older to keep your frame strong.

A reactive metal, I’m soft and silvery in appearance, but I’m a bit harder on the inside. When my ions dissolve in water, it becomes “hard”—detergents won’t lather, soap forms a surface scum, and limescale develops on faucets.

I’ve been known for hundreds of years and am found in common compounds such as lime, cement, chalk, and limestone. All of these are white, have been used in construction, and also have the ability to neutralize acid.

Date of discovery: 1808

- Density 1.550 g/cm<sup>3</sup>
- Melting point 842°C (1,548°F)
- Boiling point 1,484°C (2,703°F)



Ca



# 38 Strontium

## ● The Alkaline Earth Metals

✧ Symbol: Sr

✧ Atomic number: 38

✧ Atomic weight: 87.62

✧ Color: Silvery

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I'm Scottish, named after the town of Strontian where I was discovered. You may see me as a shy, run-of-the-mill, silver-colored metal, but I've got a few surprises up my sleeve. I'll catch your eye with the stunning crimson colors that I give to fireworks. Today my main use is as an additive in the glass of TV sets and computer monitors.

My sneaky radioactive isotope, strontium-90, has the eerie ability to mimic calcium and get absorbed inside growing bones. It releases harmful beta-particle radiation, which causes cancer. In the mid-1900s, nuclear-bomb testing meant that there was a lot of me around. I began to build up in the bodies of children. Luckily, the testing was stopped when scientists realized the potentially horrible consequences.

Date of discovery: 1790

- Density 2.630 g/cm<sup>3</sup>
- Melting point 777°C (1,431°F)
- Boiling point 1,382°C (2,520°F)





Sr



# 56 Barium



## The Alkaline Earth Metals

- ★ Symbol: Ba
- ★ Atomic number: 56
- ★ Atomic weight: 137.33
- ★ Color: Silver-white
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic

One of the heavy metals, I'm a real rocker and more reactive than calcium. My carbonate salt is a deadly rat poison, but my sulfate salt is insoluble and totally indigestible. It's used for "barium meals," which are neither tasty nor nutritious, but are ideal for seeing how you are digesting your food. When excited, my ions give off an apple-green color.



Barium

Date of discovery: 1808

- Ba
- Density 3.510 g/cm<sup>3</sup>
  - Melting point 727°C (1,341°F)
  - Boiling point 1,870°C (3,398°F)



# Radium 88

The Alkaline Earth Metals

- ★ Symbol: Ra
- ★ Atomic number: 88
- ★ Atomic weight: 226.03
- ★ Color: Silver-metallic
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



I am the heaviest of the gang and a completely captivating character. I shine in any social situation. Bright and luminescent (I was used in glow-in-the-dark paint), I am a real stunner. I have the power to ionize air with the radioactive alpha particles that I give off, creating a crackling bright blue aura around me. My name comes from the Latin *radius*, meaning "ray."

- Density 5.000 g/cm<sup>3</sup>
- Melting point 700°C (1,292°F)
- Boiling point 1,737°C (3,159°F)

Ra

Date of discovery: 1898

# CHAPTER 3

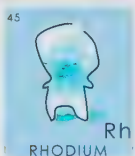
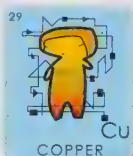
## The Transition Elements

## Groups 3–12



Stuck in the middle of the periodic table, the transition elements are a motley crew of roughnecks. Strapping, robust metals, these guys get involved in literally thousands of industrial applications. Many are catalysts—movers and shakers that kick-start all sorts of important manufacturing reactions. Others use their amazing ability to bond with a wide variety of other elements to form alloys—some of which have changed civilization forever. But it's not all grit and grime: the transition elements love to show up in a dazzling variety of highly colored forms.





# 21 Scandium

## The Transition Elements



✧ Symbol: Sc

✧ Atomic number: 21

✧ Atomic weight: 44.956

✧ Color: Silvery-white

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I'm the very first transition element but don't make a fuss over me. I'm a bit shy. I spend so much time hanging out with the lanthanoids that I'm often included with them in a group called the "rare earth" elements. My name comes from the Latin word for Scandinavia (*Scandia*). I give strength to posh aluminum bike frames and baseball bats.



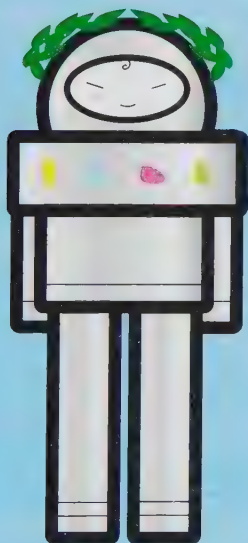
Date of discovery: 1879

Sc ● Density 2.985 g/cm<sup>3</sup>  
● Melting point 1,541°C (2,806°F)  
● Boiling point 2,830°C (5,126°F)

# Titanium 22

## The Transition Elements

- ✧ Symbol: Ti
- ✧ Atomic number: 22
- ✧ Atomic weight: 47.867
- ✧ Color: Clean, gleaming silver
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic



Titanium

I am gleaming, extremely hard, and very resistant to any type of chemical attack. As a brilliant-white dioxide compound (me plus two oxygen atoms), I make excellent paint. My main use is for superhard metal alloys whose unrivaled combo of lightness and strength means they often get used in airplane and spacecraft manufacturing.

- Density 4.507 g/cm<sup>3</sup>
- Melting point 1,668°C (3,034°F)
- Boiling point 3,287°C (5,949°F)

Ti

Date of discovery: 1791

# 23 Vanadium

## The Transition Elements

- ✧ Symbol: V
- ✧ Atomic number: 23
- ✧ Atomic weight: 50.942
- ✧ Color: Silver-gray
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

My beauty knows no bounds. I am named after the Scandinavian goddess of beauty and love, Vanadis. Depending on my state (the charge of my various ions), I can make a rainbow of brilliant and beautiful purple, green, blue, and yellow solutions.

Like most transition metals, my colorful compounds can be used as catalysts (substances that allow chemical reactions to occur more freely). I am an essential catalyst in the “contact process” that is used to manufacture sulfuric acid, arguably the most important industrial chemical in the world today. I make up part of a crucial steel alloy that was used in Henry Ford’s Model-T cars, so without me, there may never have been an auto industry.

Date of discovery: 1801

- Density 6.110 g/cm<sup>3</sup>
- Melting point 1,910°C (3,470°F)
- Boiling point 3,407°C (6,165°F)





V



Vanadium

# 24 Chromium

## The Transition Elements

- ✧ Symbol: Cr
- ✧ Atomic number: 24
- ✧ Atomic weight: 51.996
- ✧ Color: Supershiny silver
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

I'm totally flash. You may know me as a shiny, decorative metal on bikes and fancy kitchen equipment, but I am much more than just a pretty face. My name comes from the Greek word *chroma*, which means “color,” because I can appear in an impressive range of funky shades (different oxidation states)—from red to green, orange, and yellow. I am responsible for the brilliant red color of rubies, and I put the “stainless” into stainless steel. There's no tarnishing my record!

It's easy to take a shine to me—just polish me with a cloth. I'm almost completely resistant to corrosion. Because of this, I was once used as a protective layer (a plating) to stop steel surfaces from rusting. I gave old cars their classic, mirrored-metal look. These days, most cars use plastic.

Date of discovery: 1797

- Density 7.140 g/cm<sup>3</sup>
- Melting point 1,907°C (3,465°F)
- Boiling point 2,671°C (4,840°F)



Cr



Chromium

# 25 Manganese

## The Transition Elements

✧ Symbol: Mn

✧ Color: Silvery

✧ Atomic number: 25

✧ Standard state: Solid at 25°C (77°F)

✧ Atomic weight: 54.938

✧ Classification: Metallic

I'm a hard and brittle element. I am found in large amounts in the rocks of the ocean floor, and I'm most widely used in steel manufacturing. Steel is much stronger when it is joined with me in an alloy.

Like many of the other transition metals, I can exist in many different forms (oxidation states), and I change my appearance like an undercover agent—I can be pink, black, green, or dark purple.

Spend too long with me, and I'll mess with your mind. I play an important role in the body, but too much of me can give you "manganese madness," a terrifying psychiatric condition that causes hallucinations. I have also been associated with Parkinson's disease.

Date of discovery: 1774

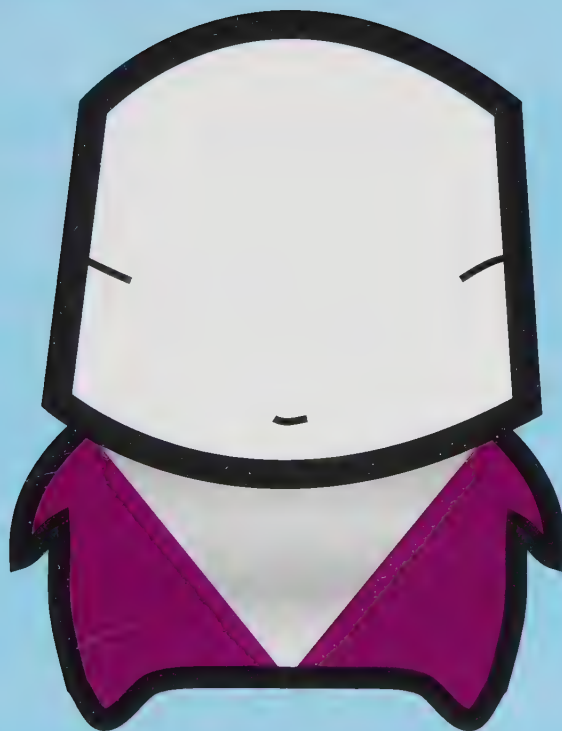
● Density 7.470 g/cm<sup>3</sup>

● Melting point 1,246°C (2,275°F)

● Boiling point 2,061°C (3,742°F)



Mn



Manganese





# 26 Iron

## The Transition Elements

- ✧ Symbol: Fe
- ✧ Atomic number: 26
- ✧ Atomic weight: 55.845
- ✧ Color: Gray
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

I am at the center of everything. I am the hub. As the main element in your blood's hemoglobin—the substance that transports oxygen throughout the body—I keep you alive. Journey to the center of Earth, and you'll find me there at the core of things. I am the most abundant element in the planet you live on, and I am at the heart of civilization, too.

I am the most important metal ever known to humankind. My use for tools and weapons transformed the ancient world; using me for construction and industrialization made the modern world. I'm most useful when I am mixed with small amounts of carbon to produce steel. But I'm not without flaws—I oxidize easily when exposed to air and water, making rust a constant problem.

Earliest known use: c. 2500 B.C.

- Density 7.874 g/cm<sup>3</sup>
- Melting point 1,538°C (2,800°F)
- Boiling point 2,861°C (5,182°F)



Fe



Iron

# 27 Cobalt

## The Transition Elements

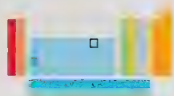
- ✧ Symbol: Co
- ✧ Atomic number: 27
- ✧ Atomic weight: 58.933
- ✧ Color: Gray
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Mysterious and attractive, I am the gremlin of the underworld. German miners called me *kobold* ("goblin"). They thought that I stopped them from getting to other more valuable metals, such as silver. For centuries, my compounds have been used to add color to glass. Blue is my best-known shade, but green and pink also feature.

Date of discovery: 1735



- Co
- Density 8.900 g/cm<sup>3</sup>
  - Melting point 1,495°C (2,723°F)
  - Boiling point 2,927°C (5,301°F)



# Nickel 28

## The Transition Elements

- ★ Symbol: Ni
- ★ Atomic number: 28
- ★ Atomic weight: 58.693
- ★ Color: Silvery
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



I'm a devil in disguise, often mistaken for copper. My name comes from the German word *kupfernickel* ("devil's copper"). I love hanging out with the other transition elements, and I'm great at forming alloys to make materials stronger and more resistant to corrosion. You'll find me charging around batteries and in special heat-resistant materials.

- Density 8.908 g/cm<sup>3</sup>
- Melting point 1,455°C (2,651°F)
- Boiling point 2,913°C (5,275°F)

Ni

Date of discovery: 1751

# 29 Copper

## The Transition Elements

✧ Symbol: Cu

✧ Atomic number: 29

✧ Atomic weight: 63.546

✧ Color: Reddish

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I am an age-old metal that gave birth to whole chunks of history and launched civilizations. As a pure metal or mixed with tin to make bronze, I have been used for hundreds of years to make ornaments and practical tools. Along with tin, I formed the basis of the Bronze Age.

I am unique among metals in that I have a red hue, but some of my salts are a vivid blue. In fact, many sea creatures have blue blood because of my presence.

I'm the poor relation in a very well-to-do family. Along with silver and gold, we're known as the "coinage metals." However, these days I'm only used in very small amounts in pennies (along with zinc). I am an exceptional conductor of electricity and heat, so I'm also used in wiring.

Earliest known use: c. 4500 B.C.

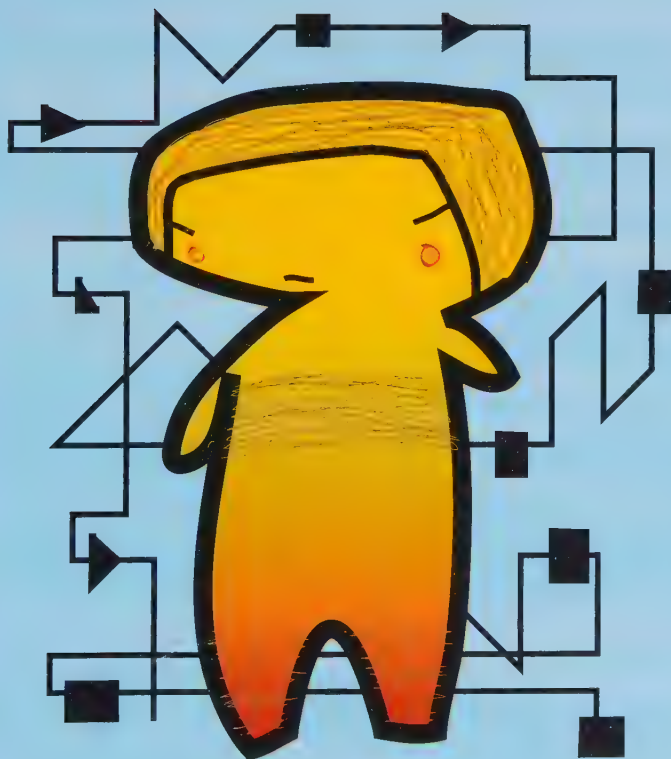
● Density 8.920 g/cm<sup>3</sup>

● Melting point 1,084.62°C (1,984.32°F)

● Boiling point 2,927°C (5,301°F)



Cu



Copper

# 30 Zinc

## The Transition Elements

- ✧ Symbol: Zn
- ✧ Atomic number: 30
- ✧ Atomic weight: 65.38
- ✧ Color: Bluish-gray
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Here to protect and serve, I'm more useful than you'd ever zinc! I'm a very sociable element that's always happy to mix in with other metals. Brass is probably my most well-known alloy, formed when I get together with copper. On my own I can be found in batteries.

With a thin layer of my atoms, I "galvanize" steel, stopping water and oxygen from rusting it away. Even if I am scratched and the steel gets exposed, I quickly form zinc oxide before iron in the steel has a chance to corrode. I also protect people from sunburn as the white zinc oxide sunblock that can be seen on the noses of lifeguards.

What's more, I'm an essential element for lots of body processes, and I can be taken as a dietary supplement.

Date of discovery: 1500

- Density 7.140 g/cm<sup>3</sup>
- Melting point 419.53°C (787.15°F)
- Boiling point 907°C (1,665°F)

Zn



Zinc

# 39 Yttrium

## The Transition Elements

- ✧ Symbol: Y
- ✧ Atomic number: 39
- ✧ Atomic weight: 88.906
- ✧ Color: Dullish white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Rare yet unspectacular as a metal, I make a stunning additive. I spice up all sorts of chemical compounds to make superhard crystals with surprising properties. For example, YAG crystals generate lasers that slice through metal, while YBCO crystals are great superconductors. Like my buddy scandium, I am a “rare earth” element.

Date of discovery: 1794



Y

- Density 4.472 g/cm<sup>3</sup>
- Melting point 1,526°C (2,779°F)
- Boiling point 3,336°C (6,037°F)

# Zirconium 40

## The Transition Elements

- ★ Symbol: Zr
- ★ Atomic number: 40
- ★ Atomic weight: 91.224
- ★ Color: Silvery-white
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Zirconium

A tough little customer. I'm so heat-resistant that they use me as a ladle for molten metal. I'm impervious to chemical attacks and strong enough to line nuclear reactors. As zirconia, I make gritty little crystals that are as hard as diamond (and just as pretty). Cutting blades made from me are unbelievably sharp. Boy, have I got the edge!

- Density 6.511 g/cm<sup>3</sup>
- Melting point 1,855°C (3,371°F)
- Boiling point 4,409°C (7,968°F)

Zr

Date of discovery: 1824



# 41 Niobium

## The Transition Elements

- ★ Symbol: Nb
- ★ Atomic number: 41
- ★ Atomic weight: 92.906
- ★ Color: Gray-white
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic

I'm named after the Greek goddess Niobe, daughter of Tantalus, and bear quite a likeness to tantalum. I am a pretty, metal with wild blue, green, yellow, purple, and violet oxides. I like to play it cool and don't easily get involved in chemistry, but you'll see me winking at you occasionally from belly piercings and in superalloys used in rockets.

Date of discovery: 1801



Niobium

- Nb
- Density 8.57 g/cm<sup>3</sup>
  - Melting point 2,477°C (4,491°F)
  - Boiling point 4,744°C (8,571°F)



# Molybdenum 42

The Transition Elements

★ Symbol: Mo

★ Atomic number: 42

★ Atomic weight: 95.96

★ Color: Gray

★ Standard state: Solid at 25°C (77°F)

★ Classification: Metallic



## Molybdenum

I am your bona fide tough nut, so don't go calling me Molly. When I am added to steel, I make it superresilient and heat-resistant. I am often found mixed up with lead ores, and my name even means "like lead." I am a great friend to growing plants because I help them to capture nitrogen from the atmosphere for their nutrition.

- Density 10.280 g/cm<sup>3</sup>
- Melting point 2,623°C (4,753°F)
- Boiling point 4,639°C (8,382°F)

Date of discovery: 1781

# Mo

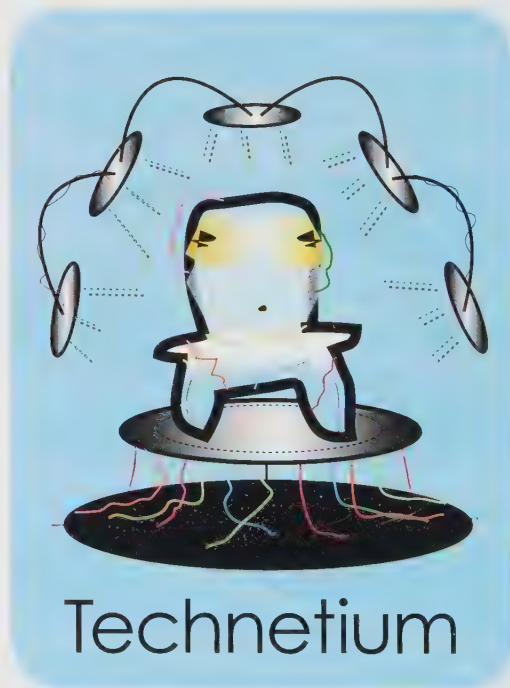
# 43 Technetium



## The Transition Elements

- ✧ Symbol: Tc
- ✧ Atomic number: 43
- ✧ Atomic weight: 97.907
- ✧ Color: Shiny gray
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Boo! You wouldn't expect to find a radioactive fellow like me stuck here in the middle of the stable transition elements. But there you go! I'm a nuclear waste product, but a force for the good. My radioactivity allows doctors to look inside bodies and seek out tumors. Tens of thousands of people are injected with me every single day.



Date of discovery: 1936

- Tc
- Density 11.5 g/cm<sup>3</sup>
  - Melting point 2,157°C (3,915°F)
  - Boiling point 4,265°C (7,709°F)



# Ruthenium 44

## The Transition Elements

- ★ Symbol: Ru
- ★ Atomic number: 44
- ★ Atomic weight: 101.07
- ★ Color: Silver mirror
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



I am a secretive element. Not many people have heard of me, and I'd like to keep it that way. I am a member of the flashy platinum group of metals, but I'm not as expensive as some of them. I'm mainly used in electrical circuits, where my superhardness resists general wear and tear. You'll also find me in the nibs of connoisseurs' pens.

- Density 12.37 g/cm<sup>3</sup>
- Melting point 2,334°C (4,233°F)
- Boiling point 4,150°C (7,502°F)

Ru

Date of discovery: 1844

# 45 Rhodium

## The Transition Elements

- ✧ Symbol: Rh
- ✧ Atomic number: 45
- ✧ Atomic weight: 102.91
- ✧ Color: Silvery-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

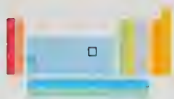
I am reassuringly reluctant to react and I'm really rare, which makes me pretty darn expensive. I am untouchable—acids strong enough to dissolve gold won't get anywhere near me. Even so, I'm a dab hand at breaking down molecules. You'll find me with platinum and palladium, tackling greenhouse gases in catalytic converters.



Date of discovery: 1803

- Rh
- Density 12.45 g/cm<sup>3</sup>
  - Melting point 1,964°C (3,567°F)
  - Boiling point 3,695°C (6,683°F)





# Palladium 46

## The Transition Elements

- ★ Symbol: Pd
- ★ Atomic number: 46
- ★ Atomic weight: 106.42
- ★ Color: Silvery
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Palladium

I'm a wizard all around the industrial world because of my amazing skill as a catalyzer of reactions. This makes me even more sought after than my close cousin, platinum. The secret lies in my surface pores. Hard at work in the catalytic converters of modern cars, I can potentially save the planet from harmful hydrocarbon emissions.

- Density 12.023 g/cm<sup>3</sup>
- Melting point 1,554.9°C (2,830.82°F)
- Boiling point 2,963°C (5,365°F)

Pd

Date of discovery: 1803

# 47 Silver

## The Transition Elements

- ✧ Symbol: Ag
- ✧ Atomic number: 47
- ✧ Atomic weight: 107.87
- ✧ Color: Silver
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

I'm as lustrous and luscious as a shining star! Whether made into money, jewelry, or candlesticks, I have always been coveted for my short-lived shininess. But I always lose out to gold because I can't help forming silver sulfide when I come into contact with air. This forms a layer of black tarnish that needs to be cleaned off.

I'm soft and easy to work with. Dentists use a little of me in so-called silver fillings (which are really mostly mercury). My conductivity is first-rate, making me popular in electrical devices. As light-sensitive silver bromide and silver iodide compounds, I was coated onto celluloid film, capturing photos and movies for the "silver screen," but digital cameras have killed off color film. Perhaps I'll become more famous for my antibacterial properties.

Earliest known use: c. 3000 B.C.

- Density 10.490 g/cm<sup>3</sup>
- Melting point 961.78°C (1,763.2°F)
- Boiling point 2,162°C (3,924°F)



Ag



# 48 Cadmium

## The Transition Elements

- ✧ Symbol: Cd
- ✧ Atomic number: 48
- ✧ Atomic weight: 112.41
- ✧ Color: Bluish silver-gray
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Just another gray, shiny transition metal, you might think. I'm a superstable element, which means that when I'm mixed into steel, or used to plate it, the steel doesn't corrode. Boor-ring! But wait—beneath my bog standard exterior, I'm a flamboyant show-off. I've got swagger!

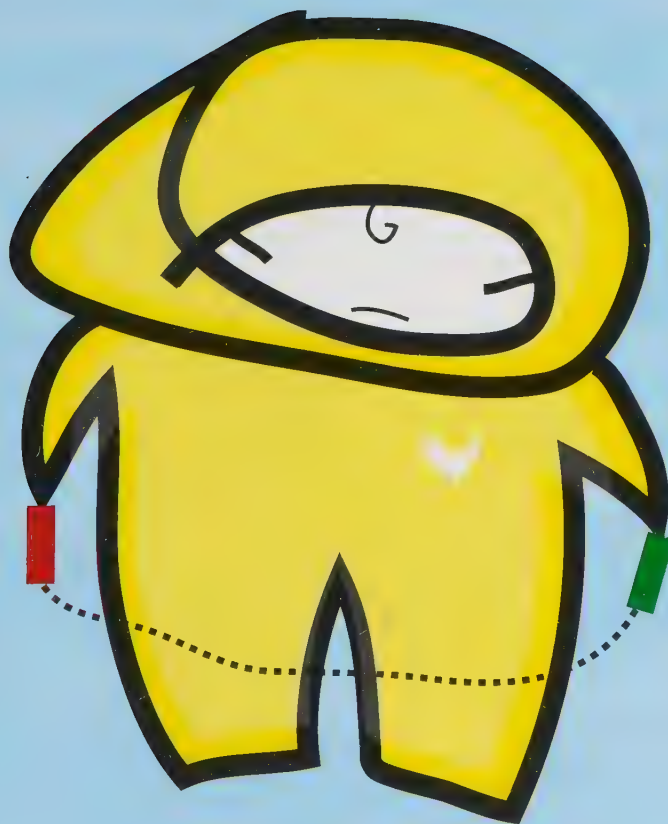
You see, when my atoms combine with other atoms and molecules, I burst out in bright reds, wild yellows, and glorious greens. My compounds make great paints. The famous artist Monet used to swear by my "cadmium yellow"! I also team up with nickel in rechargeable batteries. Like most braggers, too much of me will make you sick. Like mercury and lead, I tend to build up in the body if I make my way into water supplies and the food chain. This is why it's so important to recycle your batteries properly!

Date of discovery: 1817

- Density 8.65 g/cm<sup>3</sup>
- Melting point 321.07°C (609.93°F)
- Boiling point 767°C (1,413°F)



Cd



Cadmium



# 72 Hafnium

## The Transition Elements



- ✧ Symbol: Hf
- ✧ Atomic number: 72
- ✧ Atomic weight: 178.49
- ✧ Color: Shiny steel
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

It's what you do, not what you say that's important. I'm a rugged guy who mops up stray neutrons in the raging fires of nuclear reactors. Superalloys made with me are so strong and heat-resistant that they're used for space vehicles. Mixed with tungsten and carbon, I have the highest melting point of any known compound.



Hafnium

Date of discovery: 1922

- Hf
- Density 13.31 g/cm<sup>3</sup>
  - Melting point 2,233°C (4,051°F)
  - Boiling point 4,603°C (8,317°F)

# Tantalum 73

## The Transition Elements

- ★ Symbol: Ta
- ★ Atomic number: 73
- ★ Atomic weight: 180.95

- ★ Color: Blue-gray
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Tantalum

I'm one exotic dude! I come from the Democratic Republic of the Congo, in Africa, but you'll often find me much closer to home. I'm used to store, charge, and even out the current in almost every miniature electronic device you can think of. I'm totally corrosion-resistant and one of only two metals used for replacement body parts. Tantalizing!

- Density 16.65 g/cm<sup>3</sup>
- Melting point 3,017°C (5,463°F)
- Boiling point 5,458°C (9,856°F)

Ta

Date of discovery: 1802

# 74 Tungsten

## The Transition Elements



✧ Symbol: W

✧ Atomic number: 74

✧ Atomic weight: 183.84

✧ Color: Gray-white

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I'm one tough cookie, with the highest melting point of all metals and a boiling point close to 6,000°C (11,000°F), so you'll find me hard to liquefy and boil. In fact, you'll find me just plain harder than nails! I can be found protecting soldiers as bulletproof armor plating, and I bring light to the world in the filaments of lightbulbs.



Tungsten

Date of discovery: 1783

W

- Density 19.250 g/cm<sup>3</sup>
- Melting point 3,422°C (6,192°F)
- Boiling point 5,555°C (10,031°F)



# Rhenium 75

## The Transition Elements

- ★ Symbol: Re
- ★ Atomic number: 75
- ★ Atomic weight: 186.21

- ★ Color: White-gray
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Rhenium

Check me out! I am a truly rare, superexpensive substance. There's so little of me about, I was the last stable, naturally occurring element to be found. I am incredibly hard and heat-resistant. I just refuse to go soft, and this makes me a big player in jet-engine and rocket-booster superalloys. Here's a little-known fact: I was almost called "nipponium."

- Density 21.02 g/cm<sup>3</sup>
- Melting point 3,186°C (5,767°F)
- Boiling point 5,596°C (10,105°F)

Re

Date of discovery: 1925

# 76 Osmium

## The Transition Elements

- ✧ Symbol: Os
- ✧ Atomic number: 76
- ✧ Atomic weight: 190.23
- ✧ Color: Faint silver-blue
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Iridium and I battle it out for the title of densest element. I'm winning at the moment, but perhaps we should share the honors, since I'm always hanging out with him. Together, we're called osmiridium and are used for fancy pen nibs (we've sure got the *write* stuff). Many of my compounds are stinky—you could call me a “smell-ement!”

Date of discovery: 1803



Osmium

- Os
- Density 22.61 g/cm<sup>3</sup>
  - Melting point 3,033°C (5,491°F)
  - Boiling point 5,012°C (9,054°F)





# Iridium 77

## The Transition Elements

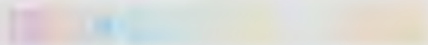
- ★ Symbol: Ir
- ★ Atomic number: 77
- ★ Atomic weight: 192.22

- ★ Color: Silver-white
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Iridium

I'm not exactly a colorful element, but I am definitely a slinky one! Substances made with me tend to shimmer and twinkle as if wearing a many-colored coat. I'm in the platinum family of tough, hard, brittle, and rare metals. Compared to me, platinum is plentiful, but if you look, you'll find me in the touch screens of cell phones and tablets.



- Density 22.65 g/cm<sup>3</sup>
- Melting point 2,466°C (4,471°F)
- Boiling point 4,428°C (8,002°F)

Date of discovery: 1748

Ir

# 78 Platinum

## The Transition Elements

- ☼ Symbol: Pt
- ☼ Atomic number: 78
- ☼ Atomic weight: 195.08
- ☼ Color: Silver-white
- ☼ Standard state: Solid at 25°C (77°F)
- ☼ Classification: Metallic

I'm the last word in good taste. Rarer and even more expensive than gold, I am a bright, shiny metal found in South Africa and Russia. I am a real ladies' metal, used to make jewelry and adored for my endlessly fascinating sheen. Steadfast and dependable, I never lose my shine because I'm resistant to corrosion.

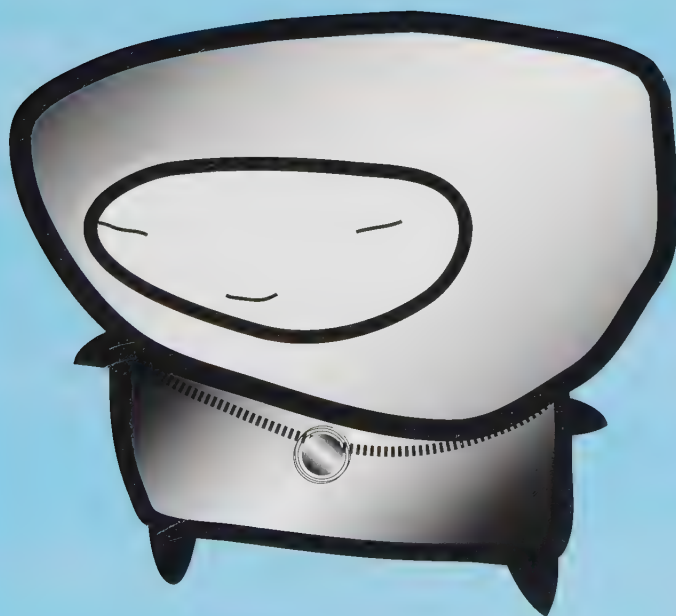
One of my most valuable uses, like so many of my fellow transition metals, is as a catalyst to get things started in industrial reactions. As steady as they come, my ability to remain unchanged made me the natural choice for the standard kilogram mass—*Le Grand Kilo*—that is stored in Paris, France, at the International Bureau of Weights and Measures. Another of my many and marvelous talents is being an essential component of anticancer drugs.

Date of discovery: 1735

- Density 21.090 g/cm<sup>3</sup>
- Melting point 1,768.3°C (3,214.9°F)
- Boiling point 3,825°C (6,917°F)



Pt



Platinum

# 79 Gold

## The Transition Elements

✧ Symbol: Au

✧ Atomic number: 79

✧ Atomic weight: 196.97

✧ Color: Gold

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I am not the rarest or the most expensive element, but I am the world's most wanted. I am the original gold-rush king, the ultimate attention seeker, and a bling party lover! At heart, I'm soft (for a metal), which makes me very easy to work with, and I can be polished to a high shine. My attraction lies in my resistance to corrosion (oxidation), meaning that I can be found in pure form inside Earth. I always remain a glistening temptation.

I am found in jewelry, in most electronic equipment (I'm a sparkling conductor of electricity), as crowns on teeth, in arthritis treatments, and, of course, as solid-gold bullion. My purity is measured in carats—24 carat is my purest form, but I can be alloyed (combined) with other metals to make 22-, 18-, 14-, and nine-carat gold.

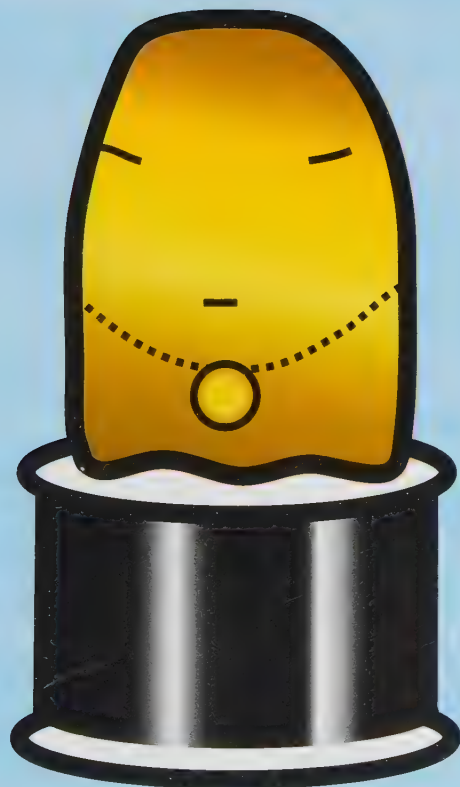
Earliest known use: c. 3000 B.C.

● Density 19.300 g/cm<sup>3</sup>

● Melting point 1,064.18°C (1,947.52°F)

● Boiling point 2,856°C (5,173°F)

Au



Gold



# 80 Mercury

## The Transition Elements

✧ Symbol: Hg

✧ Atomic number: 80

✧ Atomic weight: 200.59

✧ Color: Silvery

✧ Standard state: Liquid at 25°C (77°F)

✧ Classification: Metallic

Quick and deadly, that's me. A sinister, silver-colored killer, I am a strange and stealthy liquid metal that easily vaporizes into toxic fumes. I put the "mad" in the Mad Hatter—hatmakers who used mercury nitrate for their work often succumbed to a strange delirium called "mercury madness." My ability to poison the brain is legendary and most of the forms I take are lethal.

I tend to build up inside the bodies of animals, especially in fish that swim in waters that are polluted by me. I attack the nervous systems of creatures that eat the contaminated fish. Alchemists mistakenly thought they could use me to turn base metals into gold, and I was once widely used in mining, for tooth fillings, and in thermometers. Health and safety rules now restrict my use and I'm difficult to find.

Earliest known use: c. 1500 B.C.

● Density 13.534 g/cm<sup>3</sup>

● Melting point -38.83°C (-37.89°F)

● Boiling point 356.73°C (674.11°F)

Hg



Mercury

# CHAPTER 4

## The Boron Elements

## Group 13



This ragtag group of elements is the periodic table's dysfunctional family. They don't gel together—some of them aren't even the same type of substance! Lonely, odd-man-out boron is an unusual powdery nonmetal, while the rest are soft, silvery, and weak metals. At the top of the group, these metals aren't especially metallic, but the farther down the group you go, the more like metals the members get. The boron elements are reactive enough to form many different compounds and are found in nature as various minerals and ores.

5



B

BORON

13



Al

ALUMINUM

31



Ga

GALLIUM

49



In

INDIUM

81



Tl

THALLIUM

113



Uut

ELEMENT 113

# 5 Boron

## The Boron Elements

- ✧ Symbol: B
- ✧ Atomic number: 5
- ✧ Atomic weight: 10.81
- ✧ Color: Brownish-black
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Nonmetallic

People make fun of my name and call me “Boring Boron.” Okay, so I’m not flamboyant and I dress in brown and black, but I’m really nice to have around. I’m a facilitator and a helpful element that gets things done—a self-starter, if I can be so bold.

Whether helping out in glass manufacturing, in detergents, or—in my guise as borax and boric acid—coaxing along chemical reactions in industry, I’m on the case. My compound boron nitrate is almost as hard as diamond.

Far from tedious, you can think of me as a maverick. I am literally the “black-brown sheep” of the boron element family, since I’m the only nonmetal among my metallic friends.

Date of discovery: 1808

- Density 2.460 g/cm<sup>3</sup>
- Melting point 2,076°C (3,769°F)
- Boiling point 3,927°C (7,101°F)





Boron

# 13 Aluminum

## The Boron Elements

- ✱ Symbol: Al
- ✱ Atomic number: 13
- ✱ Atomic weight: 26.982
- ✱ Color: Silver-gray
- ✱ Standard state: Solid at 25°C (77°F)
- ✱ Classification: Metallic

I'm light on my feet, and my pocket-battleship strength has made me a powerhouse metal. I'm a featherweight who literally punches above my weight! I offer a superior blend of strength and lightness—you can make me into airplanes, "tin" cans, and foil.

I am the third most abundant element in the world, but you have to work hard to get at me. I bind tightly to my ore, bauxite, and extracting me takes a huge amount of electrical power.

My salts help purify water by causing impurities to drop out of solutions as solids, but they have been linked to poisoning. When I show up in tap water, I have turned people's hair green and caused brain disorders.

Date of discovery: 1825

- Density 2.700 g/cm<sup>3</sup>
- Melting point 660.32°C (1,220.58°F)
- Boiling point 2,519°C (4,566°F)



Al



Aluminum

# 31 Gallium

## The Boron Elements

- ✧ Symbol: Ga
- ✧ Atomic number: 31
- ✧ Atomic weight: 69.723
- ✧ Color: Silvery
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

For a tough, shiny metal, I'm a little soppy—I melt so easily that I become liquid in your hand. For the same reason, I'm a bit of a joker. You see, a teaspoon made of me will literally disappear when used to stir tea! Paired with arsenic, I'm a hit in the electronics industry and may even come to rival silicon for the top spot.



Gallium

Date of discovery: 1875

Ga	● Density	5.904 g/cm <sup>3</sup>
	● Melting point	29.76°C (85.57°F)
	● Boiling point	2,204°C (3,999°F)



# Indium 49

The Boron Elements 

- ✧ Symbol: In
- ✧ Atomic number: 49
- ✧ Atomic weight: 114.82
- ✧ Color: Shiny silver
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic



Indium

I'm one class act, baby, believe me. A soft, sticky metal with a low melting point, when I team up with oxygen (and tin) I come into my own. Indium tin oxide is see-through and conducts electricity. It is used for solar cells and LCD displays, touch screen technology for cell phones, and window demisters for cars.

- Density 7.31 g/cm<sup>3</sup>
- Melting point 156.6°C (313.88°F)
- Boiling point 2,072°C (3,762°F)

Date of discovery: 1864

In



# 81 Thallium



## The Boron Elements

- ★ Symbol: Tl
- ★ Atomic number: 81
- ★ Atomic weight: 204.38
- ★ Color: Dullish gray
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic

I am the duck-billed platypus of the elements—with properties I've borrowed from silver, platinum, and lead, I look as if I've been cobbled together. Colorless, odorless, and tasteless, I'm almost impossible to detect, and I'm poisonous to boot. Once I'm in your body, I mimic potassium, slip inside your cells, and wreak havoc.



Date of discovery: 1861

Tl

- Density 11.85 g/cm<sup>3</sup>
- Melting point 304°C (579°F)
- Boiling point 1,473°C (2,683°F)

# Element 113 113

The Boron Elements

★ Symbol: Uut

★ Atomic number: 113

★ Atomic weight: 284.18

★ Color: Unknown

★ Standard state: Solid at 25°C (77°F)

★ Classification: Metallic



Element 113

Things have gotten heavy around here, man. I was discovered in 2004, and I still have no name. No sooner am I brought to life in the dark of a particle-accelerator tube than I start winking out of existence: 20 seconds, and I'm half gone. Formed when element 115 decays, I can also be made by smashing bismuth and zinc nuclei together.

- Density 16 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

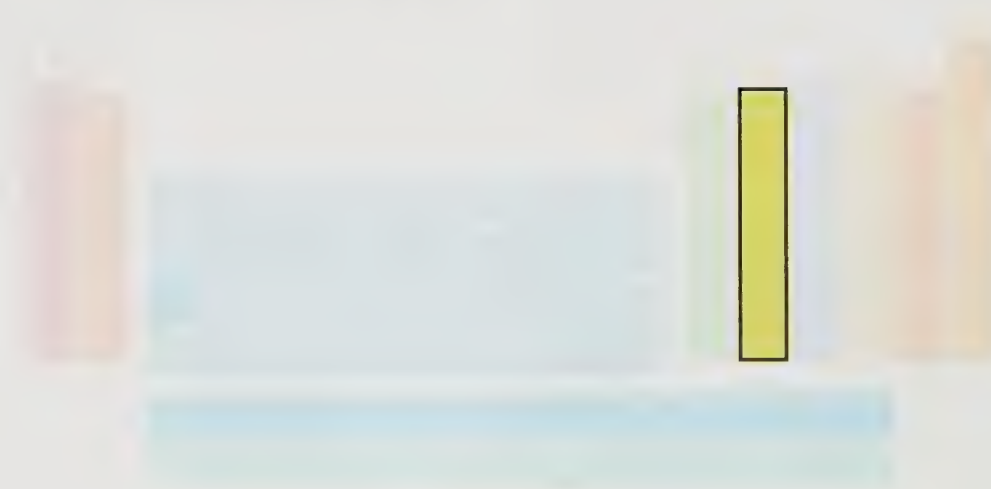
Uut

Date of discovery: 2004

# CHAPTER 5

## The Carbon Elements

## Group 14



Unpredictability hangs like a magician's cloak over this group of tricky chemicals. They have very few striking similarities. Carbon is a hard (and even sometimes transparent) nonmetal, while tin and lead are softer metals. Like Group 13, the carbon elements get more metallic toward the bottom of the table. The members form a bewildering variety of different compounds, so perhaps it would be better to consider each element as an individual, rather than as part of a collection of like-minded substances.

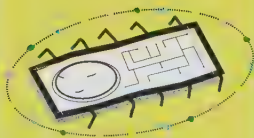
6



C

CARBON

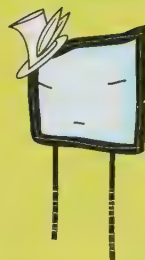
14



Si

SILICON

32



Ge

GERMANIUM

50



Sn

TIN

82



Pb

LEAD

114



Fl

FLEROVIUM

# 6 Carbon

## The Carbon Elements

- ★ Symbol: C
- ★ Atomic number: 6
- ★ Atomic weight: 12.011
- ★ Color: Black
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Nonmetallic

Hah-yah! Wherever you look, I'm there. Like a ninja, there's no escaping me! A master of the black arts, I'm a stealthy element and can morph into many forms—black charcoal, hard and brilliant diamond, slippery graphite, wonder material graphene, and lovely buckminsterfullerene balls. My ability to form several types of chemical bonds with myself means I can whip myself into all sorts of shapes. With so many different guises, there's a whole branch of “organic” chemistry devoted to me.

I form the bulk of all living matter. Almost everything you eat—fats, sugars, and fiber—is a carbon-based compound. I move around the food chain in what's called “the carbon cycle.” I'm released from food when you breathe and in your body waste, absorbed by plants, and then eaten again.

No known date of discovery

- Density 2.267 g/cm<sup>3</sup>
- Melting point 3,500°C (6,400.6°F)
- Boiling point 4,027°C (7,281°F)





C



Carbon

# 14 Silicon

## The Carbon Elements

- ✧ Symbol: Si
- ✧ Atomic number: 14
- ✧ Atomic weight: 28.085
- ✧ Color: Glassy off-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Nonmetallic

My beguiling charms make computers run and power the digital age. Combined with boron or phosphorus, I become a semiconducting sorcerer. These special powers gave birth to the silicon chip and the Computer Age. Silicon Valley in California is named after me.

I take many different forms. As the second most abundant element on Earth, I crop up in sand, quartz, flint, and countless other minerals. As silicone (a long chain made up of me, oxygen, and organic chemicals), I'm in lubricants, adhesives, and body implants.

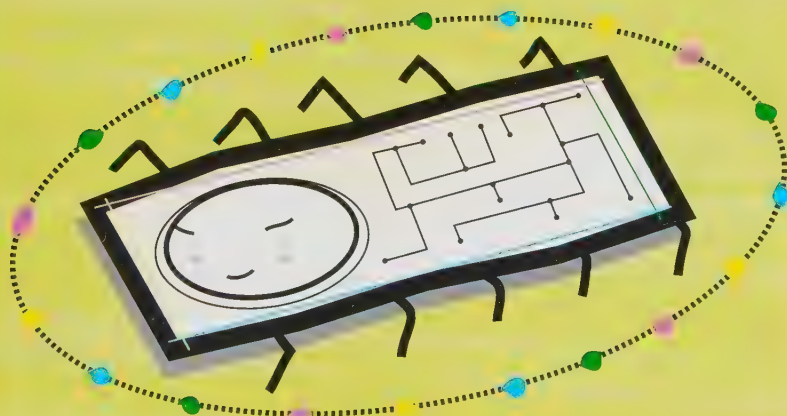
In glass, I'm perfectly clear. In quartz watches and clocks, I keep time, while as silica gel, I ensure that products are moisture-free. You'll find me inside sachets, packed inside boxes of electrical goods.

Date of discovery: 1824

- Density 2.330 g/cm<sup>3</sup>
- Melting point 1,414°C (2,577°F)
- Boiling point 2,900°C (5,252°F)



Si



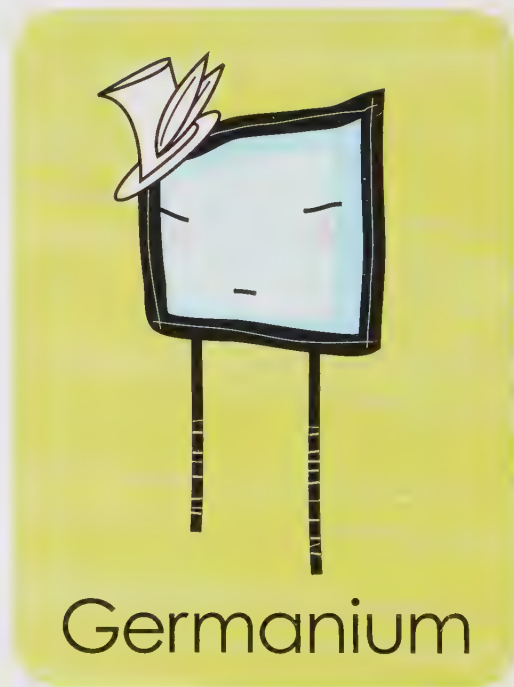
Silicon

# 32 Germanium

## The Carbon Elements

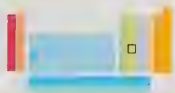
- ✧ Symbol: Ge
- ✧ Atomic number: 32
- ✧ Atomic weight: 72.63
- ✧ Color: Shiny gray-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metalloid

I am the granddaddy of the electronics industry. Poised somewhere in between a metal and a nonmetal, I have special abilities as a semiconductor. I was used in the very first transistors, but have now been replaced by silicon. Nonetheless, I make myself useful in fiber-optic cables, flashing info across the globe. Zap!



Date of discovery: 1886

- Density 5.323 g/cm<sup>3</sup>
- Melting point 938.9°C (1,720°F)
- Boiling point 2,820°C (5,108°F)



# Tin 50

## The Carbon Elements

- ★ Symbol: Sn
- ★ Atomic number: 50
- ★ Atomic weight: 118.71
- ★ Color: Dull silver
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Tin

I am too soft for my own good, and that's my problem. I melt at a low temperature (for a metal), and below 13°C (55°F), I change from a solid into a crumbly powder. I get mixed with other metals to keep me in shape. (I'm only a thin coating on "tin" cans—they're actually made of aluminum or steel.) Mingled with copper, I make bronze.

- Density 7.310 g/cm<sup>3</sup>
- Melting point 231.93°C (449.47°F)
- Boiling point 2,602°C (4,716°F)

Sn

Earliest known use: c. 3500 B.C.



# 82 Lead

## The Carbon Elements

- ✧ Symbol: Pb
- ✧ Atomic number: 82
- ✧ Atomic weight: 207.2
- ✧ Color: Dull, dark gray
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Soft and malleable, I'm so easy to work with that the ancient Romans used me for their water pipes. Over the years, I've gained a bad rep. My unfortunate ability to slip easily into the food chain—from pipes and cookware—means I'm regulated closely. But I am still used as a shield against x-rays, for roofing, and in stained glass.

No known date of discovery



Lead

- Pb**
- Density 11.340 g/cm<sup>3</sup>
  - Melting point 327.46°C (621.43°F)
  - Boiling point 1,749°C (3,180°F)



# Flerovium 114

## The Carbon Elements

- ★ Symbol: Fl
- ★ Atomic number: 114
- ★ Atomic weight: 289.19
- ★ Color: Unknown
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Flerovium

Relatively new and something of a mystery, I'm usually made by getting plutonium and calcium nuclei to bond. While some of my forms last 60 seconds before breaking down—quite a long time in the heavy element world—most have speedier half-lives. I sit with the carbon family, but scientists think I could be more like a noble gas.

- Density 14 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

Fl

Date of discovery: 1998

# CHAPTER 6

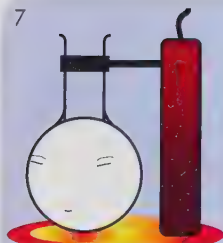
## The Nitrogen Elements

## Group 15



The “pnictogens” (say nick-toe-jens), as they are sometimes (but rarely) called, are an ancient and alchemical group with an odd collection of properties to boot. This group is a real mishmash of matter—there are metals, nonmetals, and strange metalloids; several elements exist in two different guises; and there’s a mixture of gases and solids thrown in for good measure. Like most groups in the periodic table, the elements of Group 15 get increasingly metallic toward the base. Nitrogen is a colorless gas, while bismuth is a brittle metal.

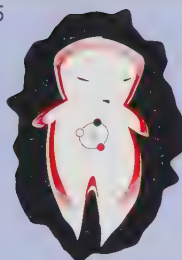
7



N

NITROGEN

15



P

PHOSPHORUS

33



As

ARSENIC

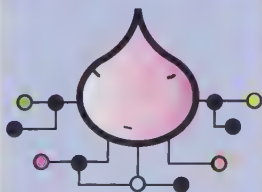
51



Sb

ANTIMONY

83



Bi

BISMUTH

115



Uup

ELEMENT 115

# 7 Nitrogen

## The Nitrogen Elements

- ✧ Symbol: N
- ✧ Atomic number: 7
- ✧ Atomic weight: 14.007
- ✧ Color: None
- ✧ Standard state: Gas at 25°C (77°F)
- ✧ Classification: Nonmetallic

On first impression I'm a regular sort, but I've got an explosive temperament. You might hardly notice me, but I make up almost 80 percent of air, and I'm essential to plant life on Earth.

I'm normally a pretty unreactive gas, made up of two atoms of nitrogen ( $N_2$ ). The triple bond between these two atoms is hard to break, and that is my hidden power. When my atoms form these bonds, they release massive amounts of energy. This makes many compounds that contain nitrogen potentially explosive!

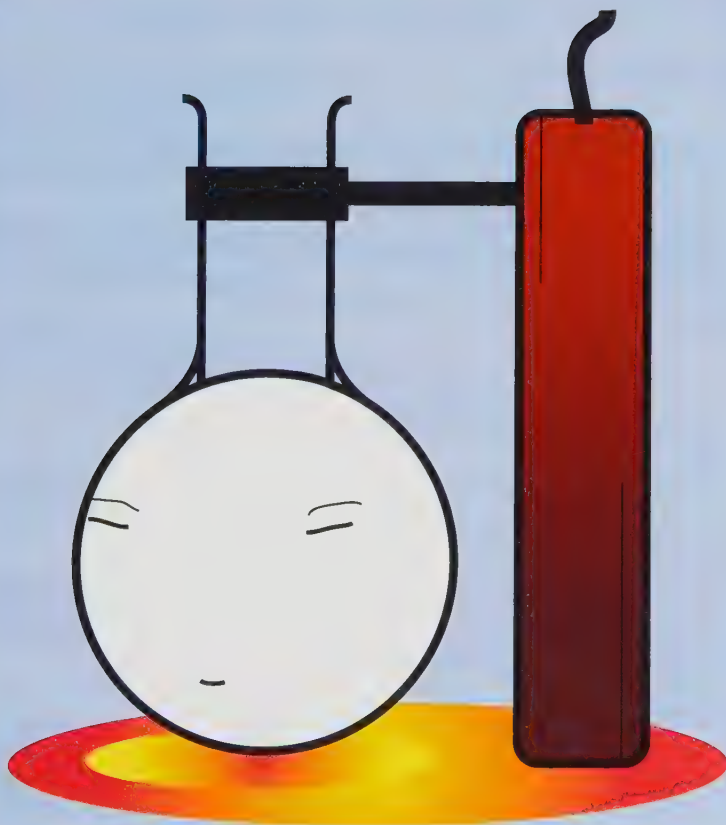
I'm very easy to extract from air. I am a spectacular coolant in liquid form. At close to  $-200^\circ\text{C}$  ( $-328^\circ\text{F}$ ), I will freeze almost anything that comes into contact with me.

Date of discovery: 1772

- Density 1.145 g/l
- Melting point  $-210.1^\circ\text{C}$  ( $-346.18^\circ\text{F}$ )
- Boiling point  $-195.79^\circ\text{C}$  ( $-320.42^\circ\text{F}$ )



N



Nitrogen



# 15 Phosphorus

## The Nitrogen Elements

- ✧ Symbol: P
- ✧ Atomic number: 15
- ✧ Atomic weight: 30.974
- ✧ Color: Black, red, or white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Nonmetallic

Like anything intriguing, I'm hard to pin down. I'm a Dr. Jekyll and Mr. Hyde element—essential to life, yet wickedly dangerous at the same time—a chameleon that appears in black, red, or white. I play a pivotal part in the DNA molecule and in the body, but I can be deadly. My white form ignites in air and even burns underwater! I can inflict terrible burns, and sadly I was used for that purpose in World War II. I am a central element in sarin—a lethal nerve gas that has been used in a number of terrorist attacks.

Arguably my most important use is in fertilizers. I am also used in many foods as phosphoric acid (an acidifying agent). You can find me in any bottle of cola, which is why you can use this soft drink as a rust remover.

Date of discovery: 1669

- Density 1.823 g/cm<sup>3</sup>
- Melting point 44.2°C (111.6°F)
- Boiling point 277°C (531°F)



P



Phosphorus

# 33 Arsenic

## The Nitrogen Elements

- ✧ Symbol: As
- ✧ Atomic number: 33
- ✧ Atomic weight: 74.922
- ✧ Color: Gray or yellow
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metalloid

Make no mistake, I'm a deadly element and a master of disguise to boot! One minute I'm a gray-colored metal, the next a yellow-colored nonmetal. I wreak havoc in developing countries, where industrial pollution allows me to sneak into the drinking water. Contamination with me causes widespread health issues. Nasty!



Earliest known use: c. 1250

- As
- Density 5.727 g/cm<sup>3</sup>
  - Melting point 817°C (1,503°F)
  - Boiling point 614°C (1,137°F)



# Antimony 51

## The Nitrogen Elements

★ Symbol: Sb

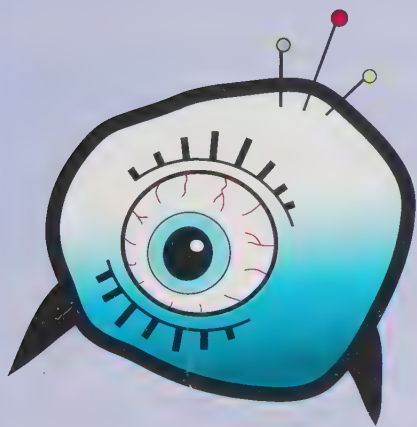
★ Atomic number: 51

★ Atomic weight: 121.76

★ Color: Silver-gray

★ Standard state: Solid at 25°C (77°F)

★ Classification: Metalloid



## Antimony

A curious and ancient metalloid, I am often found attached to other elements. Keep an eye out for me—although I'm used in mascara, I can induce violent vomiting and certain death. Like my buddy arsenic, I used to be popular among those with murder in mind. Today I'm more often used to make alloys and semiconductors.

- Density 6.697 g/cm<sup>3</sup>
- Melting point 630.63°C (1,167.13°F)
- Boiling point 1,587°C (2,889°F)

No known date of discovery

# Sb

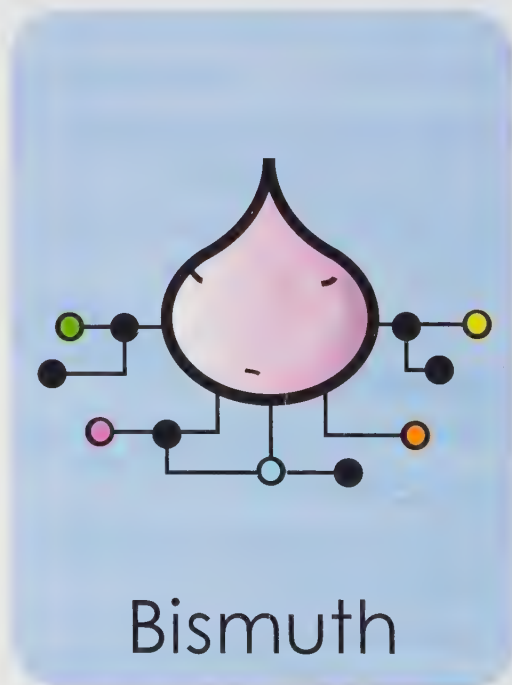
# 83 Bismuth

## The Nitrogen Elements

- ✧ Symbol: Bi
- ✧ Atomic number: 83
- ✧ Atomic weight: 208.98
- ✧ Color: Silver-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

People tend to confuse me with tin or lead, which bugs me. I'm special, too! I am the heaviest nonradioactive element. Others may decay to form more durable elements giving off radiation, but I'm stable. Because I can easily turn into a liquid, I am used as part of fire-alarm systems. When I melt in intense heat, this triggers the alarms and water sprinklers.

No known date of discovery



- Bi**
- Density 9.780 g/cm<sup>3</sup>
  - Melting point 271.3°C (520.3°F)
  - Boiling point 1,564°C (2,847°F)



# Element 115

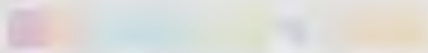
## The Nitrogen Elements

- ★ Symbol: Uup
- ★ Atomic number: 115
- ★ Atomic weight: 288.19
- ★ Color: Unknown
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Element 115

I've been around since 2004, and you won't catch me leaving the comfort of my particle accelerators. No sooner have calcium and americium cozied up (well, hammered together at eye-watering speeds) to make me than I'm falling apart again—in as little as 220 milliseconds! On the way out, I decay into element 113.



Discovered in 2004

- Density 13 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

Uup



# CHAPTER 7

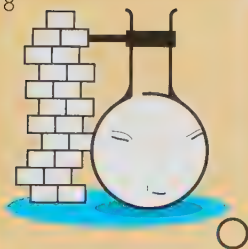
## The Oxygen Elements

## Group 16



In this neighborhood of the periodic table, the groups of elements are more like bunches of friends than family units. Nothing is truer for Group 16—it's a real mixed bag of solids, gases, nonmetals, metalloids, and even a radioactive metal—but the oxygen elements are a cosmopolitan crew that get involved in important industrial reactions and are vital to many life processes. They sport the unlikely name “the chalcogens,” which means “ore formers,” because in nature they are often found combined with metals.

8



OXYGEN

16



SULFUR

34



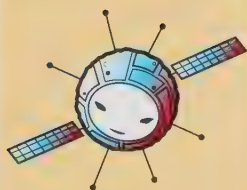
SELENIUM

52



TELLURIUM

84



POLONIUM

116



LIVERMORIUM

# 8 Oxygen

## The Oxygen Elements

- ✧ Symbol: O
- ✧ Atomic number: 8
- ✧ Atomic weight: 15.999
- ✧ Color: None
- ✧ Standard state: Gas at 25°C (77°F)
- ✧ Classification: Nonmetallic

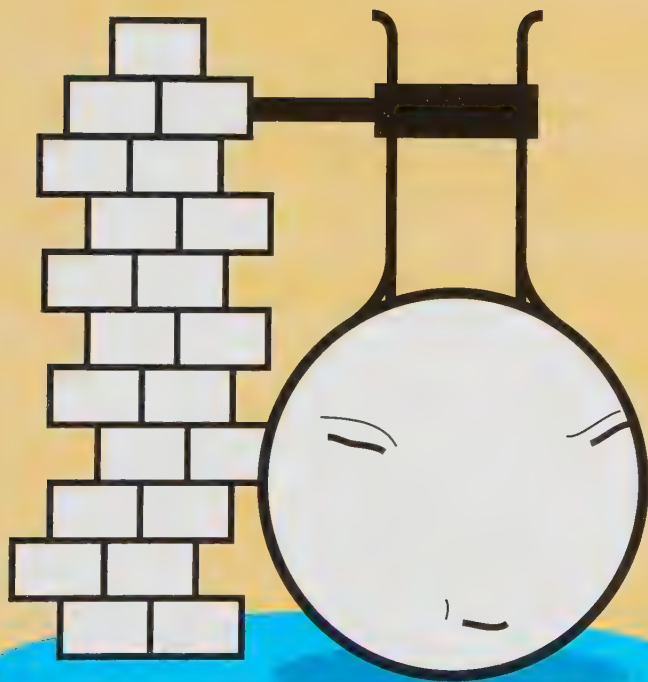
Quiet and unassuming, I'm colorless, odorless, and tasteless. Some say I lack personality, but they don't recognize true greatness. I am the powerhouse behind most chemical reactions on Earth. Without *me*, you die.

I'm a gas made up of two atoms ( $O_2$ ) that combines readily with other substances in "oxidation reactions" in order to release energy. When you breathe me in, I slip into your bloodstream. Once I'm inside your body, every single cell uses me to fuel life-sustaining chemical reactions.

I am also found in teams of three atoms ( $O_3$ ) as a gas known as ozone. When I take this form high up in the sky, I protect Earth from the Sun's harmful ultraviolet rays.

Date of discovery: 1774

- Density 1.308 g/l
- Melting point  $-218.3^{\circ}\text{C}$  ( $-360.9^{\circ}\text{F}$ )
- Boiling point  $-182.9^{\circ}\text{C}$  ( $-297.2^{\circ}\text{F}$ )



Oxygen

# 16 Sulfur

## The Oxygen Elements

- |                         |                                        |
|-------------------------|----------------------------------------|
| ✱ Symbol: S             | ✱ Color: Pale yellow                   |
| ✱ Atomic number: 16     | ✱ Standard state: Solid at 25°C (77°F) |
| ✱ Atomic weight: 32.065 | ✱ Classification: Nonmetallic          |

Sweetly smiling and dressed in pale yellow, I look as harmless as a lemon tart, but I have a wicked side. . . I am a fun-loving prankster that loves to unleash bad smells. My most vile whiffs include rotten eggs and foul skunky odors. But it's not really me—it's my compounds that stink—hydrogen sulfide ( $\text{H}_2\text{S}$ ) is the most likely culprit.

I was once known as “brimstone” and featured in fiery descriptions of hell. This reputation probably comes from the fact that I ooze from the pores of active volcanoes. When exposed to oxygen and heated, I spontaneously combust with a bright and intense light. These qualities make me an important part of gunpowder. I also cause acid rain. I am an essential element in sulfuric acid—a chemical used to make a variety of other substances.

No known date of discovery

- Density 1.960 g/cm<sup>3</sup>
- Melting point 115.21°C (239.38°F)
- Boiling point 444.72°C (832.5°F)



Sulfur



# 34 Selenium

## The Oxygen Elements

- ✧ Symbol: Se
- ✧ Atomic number: 34
- ✧ Atomic weight: 78.96
- ✧ Color: Gray
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Nonmetallic

My name comes from the Greek word *selene*, meaning “moon”—I am a remote and mysterious element. A lack of me in your diet gives you Keshan disease, which causes heart muscle failure. But when animals eat me concentrated in plants such as vetch (aka “locoweed”), I make them stagger around as if they were drunk!

Date of discovery: 1817



## Selenium

- Density 4.819 g/cm<sup>3</sup>
- Melting point 221°C (430°F)
- Boiling point 685°C (1,265°F)



# Tellurium 52

## The Oxygen Elements

- ★ Symbol: Te
- ★ Atomic number: 52
- ★ Atomic weight: 127.60
- ★ Color: Silver-gray
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Semimetal



Tellurium

Although useful in electronics, I'm a real problem child. I've been a puzzle since day one, and identifying and classifying me has been a dizzying quandary. As a corrupting influence, I am without equal. I'm about the only compound that can touch the spotless gold. In the body I cause extremely bad breath, as well as horrible body odor.

- Density 6.240 g/cm<sup>3</sup>
- Melting point 449.51°C (841.12°F)
- Boiling point 988°C (1,810°F)

Te

Date of discovery: 1783

# 84 Polonium

## The Oxygen Elements

☼ Symbol: Po

☼ Atomic number: 84

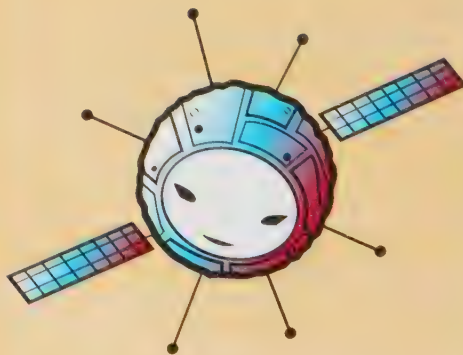
☼ Atomic weight: 208.98

☼ Color: Silvery

☼ Standard state: Solid at 25°C (77°F)

☼ Classification: Metallic

I am a radioactive fellow, discovered by the famous scientist Marie Curie. I was her first new element and she named me after her homeland, Poland. Well, that's a heartwarming tale, but aside from being used to heat spacecraft, there's little that's kind or cozy about me. I have a reputation for being a secret weapon that's used for killing spies.



## Polonium

Date of discovery: 1898

## Po

- Density 9.196 g/cm<sup>3</sup>
- Melting point 254°C (489°F)
- Boiling point 962°C (1,764°F)



# Livermorium 116

## The Oxygen Elements

- ★ Symbol: Lv
- ★ Atomic number: 116
- ★ Atomic weight: 293

- ★ Color: Unknown
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



## Livermorium

Glory-seeking scientists will stop at nothing to discover new elements. I'm a new one, made by crashing together calcium and curium nuclei. It's a complex and costly process that requires exceptional facilities. It's "Big Science," and only four labs can do it—RIKEN in Japan, Berkeley in the U.S., Dubna in Russia, and Darmstadt in Germany.

- Density 11.2 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

# Lv

Date of discovery: 2000

# CHAPTER 8

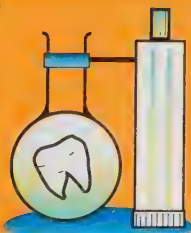
## The Halogen Elements

## Group 17



We're back in the family zone again, but this side of the periodic table is where the nonmetal elements live, separated from the metals to their left. The halogens are a close-knit group of lively, strongly colored nonmetals. They are a feisty bunch that will react violently with metals to form salts ("halogen" means "salt giver"). The elements at the top of Group 17 are yellow and green toxic gases, but as you move down through the group, things get progressively darker. . .

9



F

FLUORINE

17



Cl

CHLORINE

35



Br

BROMINE

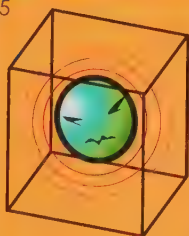
53



I

IODINE

85



At

ASTATINE

117



Uus


ELEMENT 117



# 9 Fluorine

## ■ The Halogen Elements

- |                         |                                      |
|-------------------------|--------------------------------------|
| ★ Symbol: F             | ★ Color: Pale yellow-green           |
| ★ Atomic number: 9      | ★ Standard state: Gas at 25°C (77°F) |
| ★ Atomic weight: 18.998 | ★ Classification: Nonmetallic        |

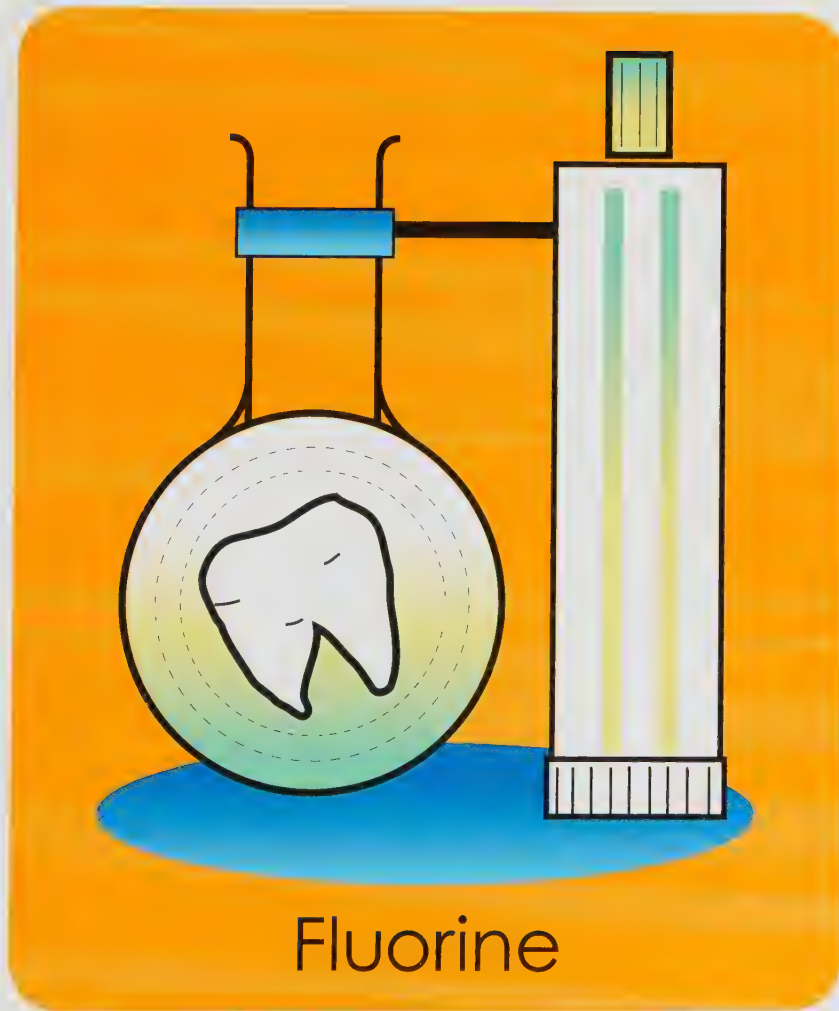


I'm a doer—a lively package set off by the perfect Hollywood smile. I am added to drinking water to help protect your teeth, and I form lots of really useful compounds—such as Teflon<sup>®</sup>, the famous nonstick coating. Running through all of the wonderful things I do is a competitive streak. I am superreactive, and I will take an electron from almost any atom or molecule in order to complete my set. This is just one of the reasons why I'm so usable and form so many nifty compounds.

The only blot on my record is my involvement with CFCs (chlorofluorocarbons)—the compounds that have done so much damage to Earth's ozone layer. I don't like to talk about it. My invasive choking smell signals my true toxic nature. So, be warned!

Date of discovery: 1886

- Density 1.553 g/l
- Melting point -219.62°C (-363.32°F)
- Boiling point -188.12°C (-306.62°F)



# 17 Chlorine

## The Halogen Elements

✱ Symbol: Cl


✱ Atomic number: 17

✱ Atomic weight: 35.45

✱ Color: Green

✱ Standard state: Gas at 25°C (77°F)

✱ Classification: Nonmetallic



You've gotta give me some respect! I'm a mean, green, killing machine. One of the halogen gang, I'm a toxic gas with a horrible history. I first became a terrifying chemical weapon during World War I, when my sinister, choking fumes killed thousands of people. I'm even bad enough to battle bacteria in the toilet bowl! But I can also keep you safe from waterborne diseases, such as cholera and typhoid fever. Adding small amounts of me to drinking water supplies has saved millions of people's lives.

Usually obtained from common salt, you'll find me in all sorts of places, from saltshakers to swimming pools (where I keep the water bacteria-free). I have also been used as an especially un-environmentally friendly pesticide called DDT and am associated with CFCs (see fluorine).

Date of discovery: 1774

● Density 2.898 g/l

● Melting point -101.5°C (-150.7°F)

● Boiling point -34.04°C (-29.27°F)



Cl




Chlorine



# 35 Bromine

## ■ The Halogen Elements

- |                         |                                         |
|-------------------------|-----------------------------------------|
| ✧ Symbol: Br            | ✧ Color: Orangish-brown                 |
| ✧ Atomic number: 35     | ✧ Standard state: Liquid at 25°C (77°F) |
| ✧ Atomic weight: 79.904 | ✧ Classification: Nonmetallic           |



I am a regal element with a long history. One of only two liquids in the periodic table (the other is mercury), I was used in the royal dye of the ancient Roman Empire—"Tyrian purple." It is made from crushed seashells, and emperors and members of the imperial family wore me proudly to show everyone else how important they were.

Today I am extracted from seawater, and as an element, you'll find me to be a pungent-smelling, red-brown, volatile liquid. I'm ashamed to say that my name comes from the Greek word *bromos*, meaning "stench."

Until recently, doctors used my salts to suppress mental activity in disturbed patients, but not anymore, since their toxic nature has been revealed.

Date of discovery: 1826

- Density 3.1028 g/cm<sup>3</sup>
- Melting point -7.3°C (19°F)
- Boiling point 59°C (138°F)



Br



Bromine



# 53 Iodine

## The Halogen Elements

- ✱ Symbol: I
- ✱ Atomic number: 53
- ✱ Atomic weight: 126.90
- ✱ Color: Shiny black
- ✱ Standard state: Solid at 25°C (77°F)
- ✱ Classification: Nonmetallic

I am a shiny black solid, but at room temperature I can change into a purplish gas without stopping to become a liquid. That's called "sublimation."

You'll almost never see me alone—I hang out in pairs as a gas ( $I_2$ ). I am deadly to bacteria when I'm in a solution. I am a yellow-brown liquid that stings like heck when it gets dabbed onto a cut (although this may be the fault of the liquid alcohol). My antiseptic powers are so good that I'm used to clean up inside the body after surgery.

I've been sneaking into people's diets for many years disguised in table salt, but that's a good thing—I help eliminate the horrible swellings of the neck that used to affect people who didn't have enough of me inside their bodies.

Date of discovery: 1811

- Density 4.940 g/cm<sup>3</sup>
- Melting point 113.7°C (236.66°F)
- Boiling point 184.3°C (363.7°F)



Iodine



# 85 Astatine

## The Halogen Elements

✧ Symbol: At

✧ Atomic number: 85

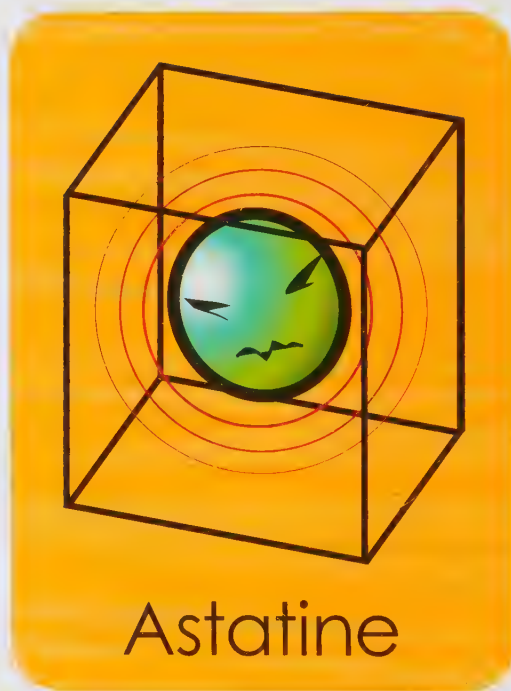
✧ Atomic weight: 209.99

✧ Color: Unknown

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Nonmetallic

Sorry, I must rush. I've just got to pop! You see, I'm superradioactive and I don't hang around, if I can help it. I have a half-life of just eight hours. I'm a rarer than rare element—no sooner have I formed by the radioactive decay of a heavier element than I break down. They even gave me a name that means “unstable”! Well, fancy that!



Date of discovery: 1940

At

● Density	6.4 g/cm <sup>3</sup>
● Melting point	302°C (576°F)
● Boiling point	230°C (446°F)

# Element 117 117

## The Halogen Elements

✧ Symbol: Uus

✧ Atomic number: 117

✧ Atomic weight: 294

✧ Color: Unknown

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Nonmetallic



Element 117

As recently as 2010, a joint team of Russian and U.S. scientists managed to make six atoms of me in a Russian laboratory. This makes me the element with the fewest number of atoms ever seen! I should be like the rest of the halogens, but first my discovery needs to be checked to see if it is genuine. Well, I ask you, the nerve of it!

- Density 7.2 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

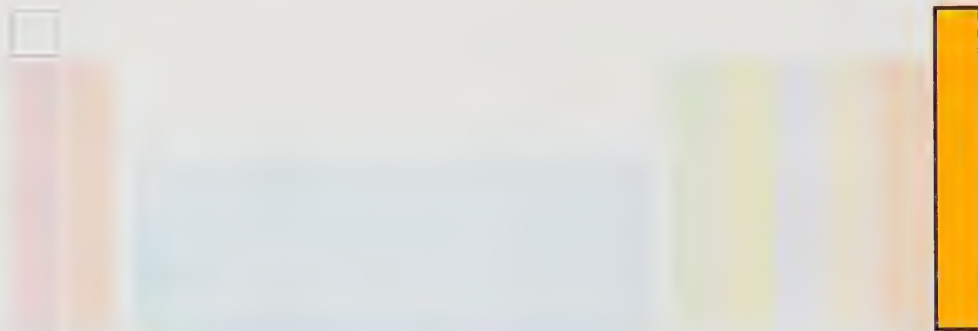
Uus

Date of discovery: 2010

# CHAPTER 9

## The Noble Gases

## Group 18



The far right of the table is the classy neighborhood, for here lives the periodic table's royal family—the so-called “noble gases.” This group is largely resistant to chemical reactions, seemingly above mixing or slumming it with the rest of the elements. They were once called the “inert gases,” meaning completely unreactive, but this isn't entirely true—some of them have been caught in clandestine clinches with other elements. They're not even that rare either—we now know that they all float around in the atmosphere, alone and aloof.

2



He  
HELIUM

10



Ne  
NEON

18



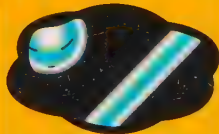
Ar  
ARGON

36



Kr  
KRYPTON

54



Xe  
XENON

86



Rn  
RADON

118



Uuo  
ELEMENT 118



# 2 Helium

## ■ The Noble Gases

✧ Symbol: He

✧ Atomic number: 2

✧ Atomic weight: 4.0026

✧ Color: None

✧ Standard state: Gas at 25°C (77°F)

✧ Classification: Nonmetallic

I prefer my own company, thank you very much. Some call me aloof, but I'm happy not to mix with the riffraff of the periodic table. I am a "noble" gas—the very first. I am completely inert, with no color, taste, or smell. I am also known as a party prankster. Gulp me from a birthday balloon, and your voice will get all squeaky!

I am produced in massive stars such as the Sun, where four hydrogen atoms fuse together, releasing enormous amounts of energy. On Earth, my nucleus is one of the products of radioactive decay—the alpha particle.

My main uses are in weather balloons and airships—which need my lofty, lighter-than-air properties—and in welding, which requires an inert, unreactive atmosphere.

Date of discovery: 1895

● Density 0.164 g/l

● Melting point -272.2°C (-458°F)

● Boiling point -268.93°C (-452.07°F)



He



# 10 Neon

## ■ The Noble Gases

✧ Symbol: Ne


✧ Atomic number: 10

✧ Atomic weight: 20.180

✧ Color: None

✧ Standard state: Gas at 25°C (77°F)

✧ Classification: Nonmetallic



I must be the funkiest element around. My name is derived from the Greek word *neos*, which means “new.” (Maybe any new element could have been christened this way, but I think it suits me very well.) Things really get going when I become excited by electrical energy—my electrons zap and zing and make me emit bright, brilliant, and stunningly colored red light. When other elements are stirred into the mix, I can produce all the colors of the rainbow. This is how neon lights are made.

Even though I am found in something as common as air, I am a member of the periodic table’s aristocracy—the noble gases. I keep myself to myself. I am a colorless, odorless, and tasteless gas, and there is virtually nothing that I will react with.

Date of discovery: 1898

● Density 0.825 g/l

● Melting point  $-248.59^{\circ}\text{C}$  ( $-415.46^{\circ}\text{F}$ )

● Boiling point  $-246.08^{\circ}\text{C}$  ( $-410.94^{\circ}\text{F}$ )



Ne



Neon



# 18 Argon

## ■ The Noble Gases

✧ Symbol: Ar

✧ Atomic number: 18

✧ Atomic weight: 39.948

✧ Color: None

✧ Standard state: Gas at 25°C (77°F)

✧ Classification: Nonmetallic

Bone idle and basically lazy, I'm totally lackluster—an odorless, colorless, and tasteless gas. I'm renowned for my unwillingness and inability to react with anything at all, but this can be a good thing—I am used as an “inert atmosphere” in potentially dangerous jobs, such as arc welding, when oxygen must be excluded in order to avoid explosions. I am also sometimes used in lightbulbs. You can even find me between the panes of some windows because I am such a poor conductor of heat.

As the third most abundant gas in Earth's atmosphere, I'm extracted from liquid air. Because I am produced when the radioactive isotope potassium-40 decays, my presence in the atmosphere is increasing with time.

Date of discovery: 1894

● Density 1.633 g/l

● Melting point -189.3°C (-308.7°F)

● Boiling point -185.8°C (-302.4°F)



Ar



Argon



# 36 Krypton

## ■ The Noble Gases

✧ Symbol: Kr

✧ Atomic number: 36

✧ Atomic weight: 83.798

✧ Color: None

✧ Standard state: Gas at 25°C (77°F)

✧ Classification: Nonmetallic

I'm elusive to say the least! My name, from the Greek *kryptos*, means "hidden," and it is aptly chosen. I'm almost completely unreactive, colorless, odorless, and tasteless, and I'm only present in the atmosphere in vanishingly small amounts. Don't confuse me with the fictional home planet of Superman and the source of his nemesis—kryptonite!



Date of discovery: 1898

Kr

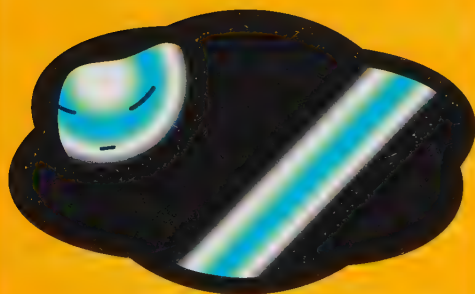
- Density 3.425 g/l
- Melting point  $-157.36^{\circ}\text{C}$  ( $-251.25^{\circ}\text{F}$ )
- Boiling point  $-153.22^{\circ}\text{C}$  ( $-243.8^{\circ}\text{F}$ )



# Xenon 54

The Noble Gases ■

- ★ Symbol: Xe
- ★ Atomic number: 54
- ★ Atomic weight: 131.29
- ★ Color: None
- ★ Standard state: Gas at 25°C (77°F)
- ★ Classification: Nonmetallic



Xenon

I'm one bright fellow, I can tell you. As far as the noble gases go, I'm a bit of a tease and can actually be persuaded to make chemical compounds. So humph to the rest of those stuffed shirts! I make arc lamps so fantastically brilliant that they are used in IMAX movie projectors and the headlights of fancy automobiles.

- Density 5.894 g/l
- Melting point -111.7°C (-169.1°F)
- Boiling point -108°C (-162°F)

Date of discovery: 1898

Xe

# 86 Radon

## ■ The Noble Gases

- ★ Symbol: Rn
- ★ Atomic number: 86
- ★ Atomic weight: 222.02
- ★ Color: None
- ★ Standard state: Gas at 25°C (77°F)
- ★ Classification: Nonmetallic

Like my other “noble” family members, I’m almost completely immune to chemical reactions, but I’m a much more spunky character than the rest. I give off harmful radioactive alpha particles, and, since I occur in granite, there is a concern that I may build up inside houses in granitic areas and pose a risk of lung cancer.

Date of discovery: 1900



- Rn
- Density 9.074 g/l
  - Melting point -71°C (-96°F)
  - Boiling point -61.7°C (-79.1°F)

# Element 118 118

The Noble Gases ■

- ★ Symbol: Uuo
- ★ Atomic number: 118
- ★ Atomic weight: 294

- ★ Color: Unknown
- ★ Standard state: Gas at 25°C (77°F)
- ★ Classification: Metallic



Element 118

I'm as synthetic as they come—the last element on today's periodic table menu. It's a really painstaking process to make superheavy elements like me. Heavy ions are crashed together for months in particle accelerators. Eventually, enough atoms are created to be detected—often as few as three or four of them!

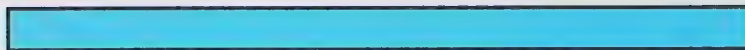
- Density 5.7 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

Uuo

Date of discovery: 2002

# CHAPTER 10

## The Lanthanoid Elements



The lanthanoids are naturally occurring heavy metals. Grouped with the transition metals, yttrium and scandium, this weighty lot are often termed “rare earth” elements. Funny thing is, they’re not all that rare, but are tricky to separate, which is why they were discovered later than many other naturally occurring elements. The plain-Jane lanthanoids have amazing magnetic- and light-amplifying properties—21st-century attributes that see them used in touch screens, wind turbines, batteries for cell phones and hybrid cars, as well as to date rocks from outer space.



57



La  
LANTHANUM

58



Ce  
CERIUM

59



Pr  
PRASEODYMIUM

60



Nd  
NEODYMIUM

61



Pm  
PROMETHIUM

62



Sm  
SAMARIUM

63



Eu  
EUROPIUM

64



Gd  
GADOLINIUM

65



Tb  
TERBIUM

66



Dy  
DYSPROSIUM

67



Ho  
HOLMIUM

68



Er  
ERBIUM

69



Tm  
THULIUM

70



Yb  
YTTERBIUM

71



Lu  
LUTETIUM



# 57 Lanthanum

## The Lanthanoid Elements

- ✧ Symbol: La
- ✧ Atomic number: 57
- ✧ Atomic weight: 138.91
- ✧ Color: Dull white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

Peek-a-boo! I'm the boss of the lanthanoid crew. We're a close-knit bunch who like to hang out together in the same minerals. This makes us really difficult to separate chemically. In fact, my name comes from the Greek word *lanthanein* meaning "escape notice."

But for a deep-cover kind of guy, I've got some pretty flash tricks. Mixed with cerium and a dash of neodymium or praseodymium, I make a crazy flammable metal called "misch metal." It's used in flints for cigarette lighters and to make showers of sparks as a special effect for movies. Special glass incorporating my oxide compound makes high-quality, superaccurate lenses for cameras. My metal also forms an essential component of rechargeable nickel-metal hydride batteries in hybrid cars. All in all, I'm worth taking the trouble to find!

Date of discovery: 1839

- Density 6.162 g/l
- Melting point 920°C (1,688°F)
- Boiling point 3,470°C (6,278°F)



La

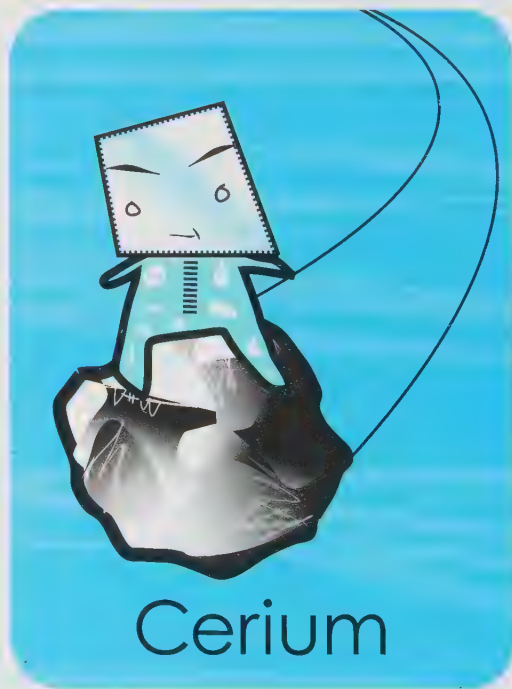


# 58 Cerium

## ■ The Lanthanoid Elements

- ✧ Symbol: Ce
- ✧ Atomic number: 58
- ✧ Atomic weight: 140.12
- ✧ Color: Silver-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

You can call me Sparky! I'm a bright fellow, used in the flints of lighters and for dramatic sparkle effects in movies. Flakes of me spontaneously burst into flame—things certainly brighten up when I'm around! I'm on a mission to save the planet: tiny nanoparticles of my oxide are added to diesel fuel, to clean up its dirty exhaust emissions.



Date of discovery: 1803

Ce	● Density	6.689 g/cm <sup>3</sup>
	● Melting point	795°C (1,463°F)
	● Boiling point	3,360°C (6,080°F)

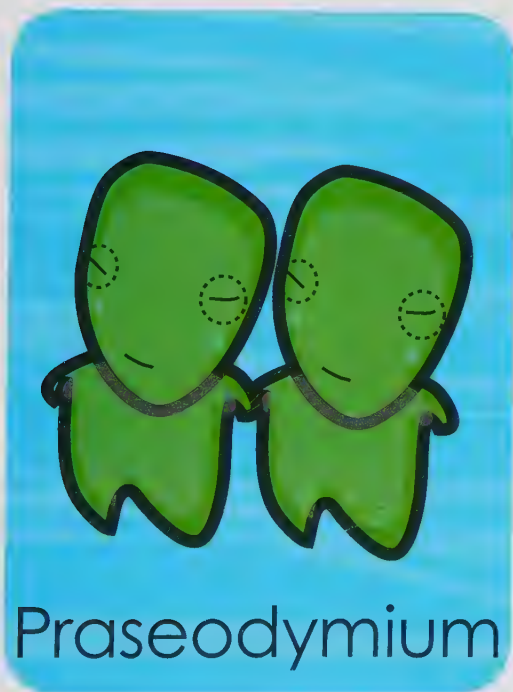


# Praseodymium 59

The Lanthanoid Elements

- ★ Symbol: Pr
- ★ Atomic number: 59
- ★ Atomic weight: 140.91

- ★ Color: Gray-whitish
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Despite my flamboyant name, I'm really a bashful element in a shy group. I'm one of the elements classed as "rare earths." We are really similar to each other (which is why we have our own special row in the periodic table). You'll find me in the "didymium" glasses that shield glassblowers' eyes and the bright lights of movie projectors. Blinding!

- Density 6.640 g/cm<sup>3</sup>
- Melting point 935°C (1,715°F)
- Boiling point 3,290°C (5,954°F)

Pr

Date of discovery: 1885

# 60 Neodymium

## The Lanthanoid Elements

✧ Symbol: Nd

✧ Atomic number: 60

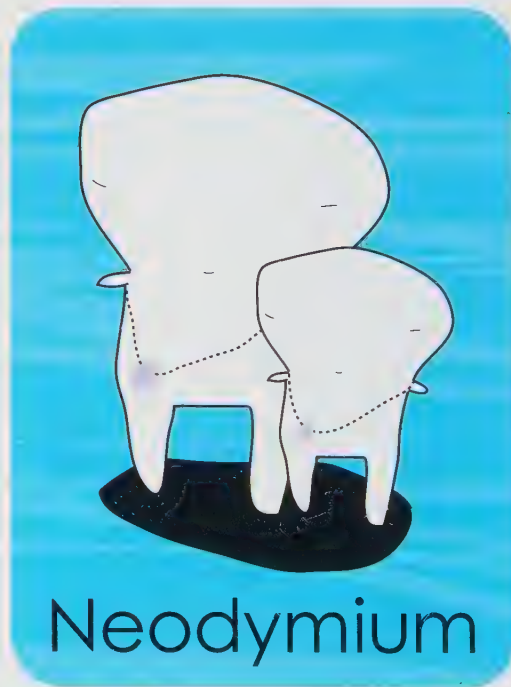
✧ Atomic weight: 144.24

✧ Color: Dull silver

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I am the great attractor—the element with the magnetic personality! Permanent magnets made with me (plus iron and boron) are thousands of times stronger than any other. You'll find me in the vibrating parts of your cell phone, in microphones and loudspeakers, in the electric motors of hybrid cars, in oil filters, and in computer hard disks.



Date of discovery: 1885

Nd

● Density	6.8 g/cm <sup>3</sup>
● Melting point	1,024°C (1,875°F)
● Boiling point	3,100°C (5,612°F)



# Promethium 61

## The Lanthanoid Elements

- ★ Symbol: Pm
- ★ Atomic number: 61
- ★ Atomic weight: 144.91

- ★ Color: Metallic
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



They call me the Bringer of Fire—beat that for a name! I'm named after the Greek hero Prometheus, who stole fire from the gods and brought it to Earth, and even though I'm surrounded by stable elements, I'm unstable, radioactive, and dangerous! I'm used in industry to gauge the thickness of sheets of plastic, metal, or paper.



- Density 7.264 g/cm<sup>3</sup>
- Melting point 1,100°C (2,012°F)
- Boiling point 3,000°C (5,432°F)

Pm

Date of discovery: 1945



# 62 Samarium

## The Lanthanoid Elements

- ✧ Symbol: Sm
- ✧ Atomic number: 62
- ✧ Atomic weight: 150.36
- ✧ Color: Lustrous silver
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

I'm a real do-gooder. You might call me the "Good Samarium" (geddit?). I'm used to date exotic rocks and in the control rods of nuclear reactors, 'cos I mop up stray neutrons. Mixed with cobalt, I make superstrong magnets that can be bashed around without losing any of their magnetism. They are used in electric guitar pickups and headphones.



Date of discovery: 1879

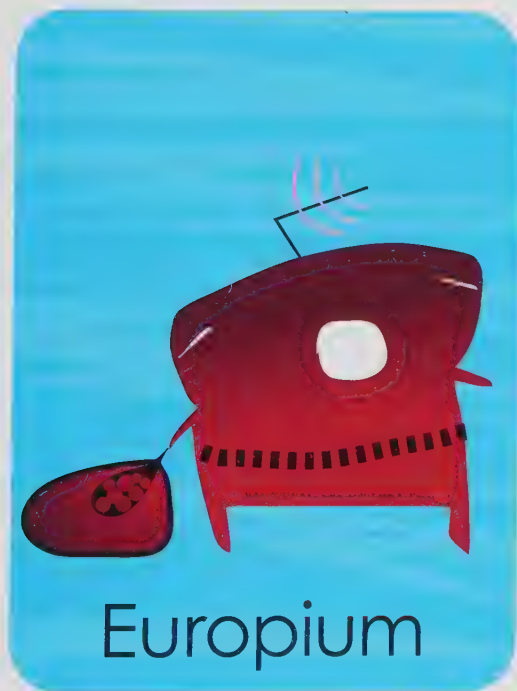
Sm	● Density	7.353 g/cm <sup>3</sup>
	● Melting point	1,072°C (1,962°F)
	● Boiling point	1,803°C (3,277°F)

# Europium 63

## The Lanthanoid Elements

- ★ Symbol: Eu
- ★ Atomic number: 63
- ★ Atomic weight: 151.96

- ★ Color: Discolored silver
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Suave and sophisticated, I'm quite the cosmopolitan European. Useful for all sorts of lighting, my compounds give off a spooky glow when light is shone on them. I help energy-efficient bulbs give out white light by combining my fluorescent red and blue glows. I also make a neat antiforgery strip on Euro banknotes. How very illuminating!

- Density 5.244 g/cm<sup>3</sup>
- Melting point 826°C (1,519°F)
- Boiling point 1,527°C (2,781°F)

Eu

Date of discovery: 1901

# 64 Gadolinium

## ■ The Lanthanoid Elements

- ✧ Symbol: Gd
- ✧ Atomic number: 64
- ✧ Atomic weight: 157.25
- ✧ Color: Silver-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

We lanthanoid elements like to keep things “plain vanilla.” No alarms. No surprises. We are so similar to each other, chemically, yet I do my best to stand out from the rest. And I happen to excel in one area in particular: when injected into the body, my magnetic properties make it easy for an MRI machine to detect and pick out very fine details.



Date of discovery: 1886



Gd	● Density	7.901 g/cm <sup>3</sup>
	● Melting point	1,312°C (2,394°F)
	● Boiling point	3,250°C (5,882°F)



# Terbium 65

## The Lanthanoid Elements

- ✧ Symbol: Tb
- ✧ Atomic number: 65
- ✧ Atomic weight: 158.93

- ✧ Color: Silver-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic



Ter-bium or not ter-bium, that is the question! Well, let's find out. Stick me in a magnetic field and watch me writhe and wriggle! Compounds made with me have the strange ability to change their length when magnetized. This funky property is used to create "terbium-charged" devices that make any flat surface act as a speaker.



- Density 8.19 g/cm<sup>3</sup>
  - Melting point 1,356°C (2,473°F)
  - Boiling point 3,230°C (5,846°F)
- Tb

Date of discovery: 1843

# 66 Dysprosium

## ■ The Lanthanoid Elements

★ Symbol: Dy

★ Atomic number: 66

★ Atomic weight: 162.50

★ Color: Bright silver

★ Standard state: Solid at 25°C (77°F)

★ Classification: Metallic

With such a downbeat name, it's no wonder I'm a moody soul. Dysprosium means "hard to get at," and I played hide-and-seek with chemists for almost 70 years. Since I'm so coy, I don't get used in many things. To be honest, there's not much I can do that one of my lanthanoid cousins can't do better or cheaper than me.

Date of discovery: 1886



Dy

- Density 8.551 g/cm<sup>3</sup>
- Melting point 1,407°C (2,565°F)
- Boiling point 2,567°C (4,653°F)



# Holmium 67

## The Lanthanoid Elements

- ✧ Symbol: Ho
- ✧ Atomic number: 67
- ✧ Atomic weight: 164.93

- ✧ Color: Silver-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic



"Holmium" your horses! I'm not magnetic in my own right, but put me in a magnetic field and I boost its strength like crazy. If you are a metal, you're going to find me irresistible! A small lump of me will soup up your run-of-the-mill bar magnet, and, used as the pole pieces in an MRI scanning machine, I'm stupendously powerful!

- Density 8.795 g/cm<sup>3</sup>
- Melting point 1,461°C (2,662°F)
- Boiling point 2,720°C (4,928°F)

Ho

Date of discovery: 1878



# 68 Erbium

## The Lanthanoid Elements



- ✧ Symbol: Er
- ✧ Atomic number: 68
- ✧ Atomic weight: 167.26
- ✧ Color: Shiny silver
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

My pretty pink ions have a magical talent with light—a small section of optical fiber doped with me “boosts” light traveling through it, so that it leaves brighter than it entered! When you use the telephone or go online, you use me to help deliver your data with blistering speed. I’m the secret behind the internet’s success!



Date of discovery: 1843

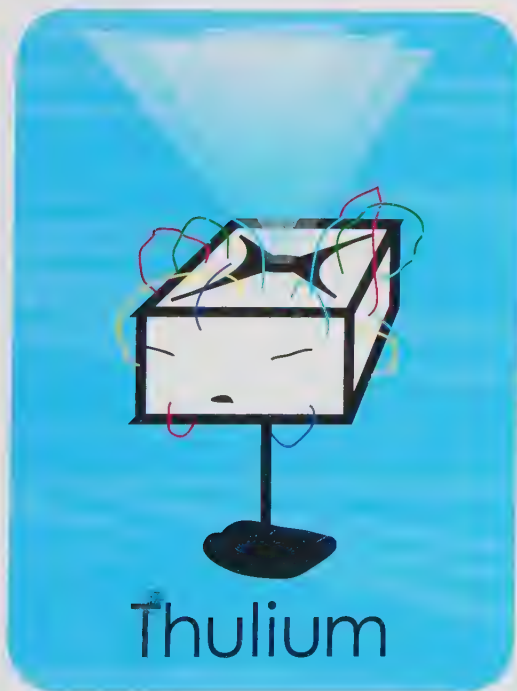
- Er
- Density 9.066 g/cm<sup>3</sup>
  - Melting point 1,529°C (2,784°F)
  - Boiling point 2,868°C (5,194°F)

# Thulium 69

## The Lanthanoid Elements

- ★ Symbol: Tm
- ★ Atomic number: 69
- ★ Atomic weight: 168.93

- ★ Color: Silver-gray
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



I'm the ugly sister of this bunch and my life is somewhat dull. While the rest of the lanthanoids are on the town, finding new jobs and teaming up in exciting technology, I tend just to sit around. Basically, I'm a bit lazy and I prefer to hide away. However, I am dragged out to be used in laser surgery and as a low-risk source of x-rays.

- Density 9.321 g/cm<sup>3</sup>
  - Melting point 1,545°C (2,813°F)
  - Boiling point 1,950°C (3,542°F)
- Tm

Date of discovery: 1879

# 70 Ytterbium

## ■ The Lanthanoid Elements

★ Symbol: Yb

★ Atomic number: 70

★ Atomic weight: 173.05

★ Color: Bright silver

★ Standard state: Solid at 25°C (77°F)

★ Classification: Metallic

I'm your affable Swedish uncle—one of four lucky elements to be named after a small town in Sweden, called Ytterby. Many of the “rare earth” elements were discovered in minerals mined in a quarry there—this is a group that definitely like to hang out together. I am used in small quantities for lasers as well as for portable x-ray machines.



Date of discovery: 1907

Yb ● Density 6.57 g/cm<sup>3</sup>  
● Melting point 824°C (1,515°F)  
● Boiling point 1,196°C (2,185°F)

# Lutetium 71

## The Lanthanoid Elements

- ★ Symbol: Lu
- ★ Atomic number: 71
- ★ Atomic weight: 174.97

- ★ Color: Silver-white
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



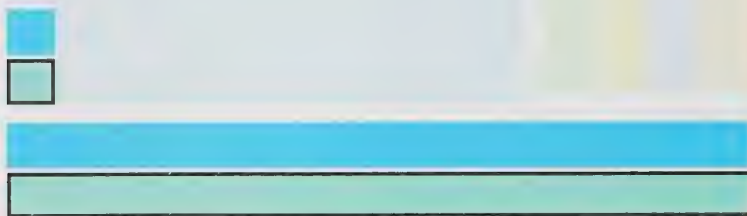
I'm the last of the lanthanoid elements—soft metals with similar habits. We're bright and silvery but tarnish easily. Chemically, we tend to get up to the same tricks. I'm a French discovery, though many of my pals are Scandinavian. Dapper and well turned out, I am one of the few corrosion-resistant "rare earth" elements.

- Density 9.841 g/cm<sup>3</sup>
  - Melting point 1,652°C (3,006°F)
  - Boiling point 3,402°C (6,156°F)
- LU

Date of discovery: 1907

# CHAPTER 11

## The Actinoid Elements



Removed from the main body of the periodic table, the actinoids are outcasts sometimes called the “f-block” elements (along with the lanthanoids). There are some seriously heavy elements here. With 89-plus protons in their nuclei, the actinoids are a bunch of dangerously radioactive misfits. Only three of them occur naturally—the rest are created artificially in nuclear reactors and particle accelerators and decay in the blink of an eye. Apart from naturally occurring uranium and thorium, these bruisers were all discovered in the 20th century.



89



Ac  
ACTINIUM

90



Th  
THORIUM

91



Pa  
PROTACTINIUM

92



U  
URANIUM

93



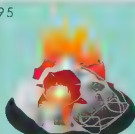
Np  
NEPTUNIUM

94



Pu  
PLUTONIUM

95



Am  
AMERICIUM

96



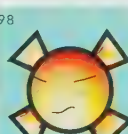
Cm  
CURIUM

97



Bk  
BERKELIUM

98



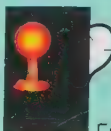
Cf  
CALIFORNIUM

99



Es  
EINSTEINIUM

100



Fm  
FERMIUM

101



Md  
MENDELEVIUM

102



No  
NOBELIUM

103



Lr  
LAWRENCIUM



# 89 Actinium

## The Actinoid Elements

★ Symbol: Ac

★ Atomic number: 89

★ Atomic weight: 227.03

★ Color: Silvery

★ Standard state: Solid at 25°C (77°F)

★ Classification: Metallic

I'm a ray of light—but there's nothing natural about me, sunshine. I'm entirely unearthly and shine with a spooky glow. You won't find me on the planet. I'm so radioactive—about 150 times more so than radium—that any atoms present when Earth formed have long broken down into other elements. New atoms of me are made in nuclear reactors.



Actinium

Date of discovery: 1889

Ac	● Density	10.07 g/cm <sup>3</sup>
	● Melting point	1,050°C (1,922°F)
	● Boiling point	3,000°C (5,972°F)

# Thorium 90

## The Actinoid Elements

- ☼ Symbol: Th
- ☼ Atomic number: 90
- ☼ Atomic weight: 232.04

- ☼ Color: Silver-white
- ☼ Standard state: Solid at 25°C (77°F)
- ☼ Classification: Metallic



I am "Mighty Thorium," named after the beefy Norse god Thor. I heat Earth's core. Radioactively, I'm a little tame and occur naturally. My combo with oxygen has the highest melting point of all oxides, so I'm used in the fabric-net mantles of some gas camping lamps, where I glow brightly in the flames and throw out my cheering light.

- Density 11.724 g/cm<sup>3</sup>
- Melting point 1,842°C (3,348°F)
- Boiling point 4,820°C (8,708°F)

Th

Date of discovery: 1828

# 91 Protactinium

## ● The Actinoid Elements

✧ Symbol: Pa

✧ Atomic number: 91

✧ Atomic weight: 231.04

✧ Color: Bright silvery shine

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I'm an eccentric fellow.  
Of no real use to anyone,  
I keep my activities to  
myself, and people leave  
me alone. Good news for  
them, I say, because my  
radioactivity is harmful.  
The atoms of most  
unstable, radioactive  
elements vanish in the  
blink of an eye, but some  
forms of me hang around  
almost forever. Well, I'm  
in no particular hurry!



Date of discovery: 1913

● Density 15.37 g/cm<sup>3</sup>  
● Melting point 1,568°C (2,854°F)  
● Boiling point 4,000°C (7,232°F)

Pa

# Uranium 92

## The Actinoid Elements

- ★ Symbol: U
- ★ Atomic number: 92
- ★ Atomic weight: 238.03

- ★ Color: Gray
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Uranium

I am a powerful force of nature. Fire a neutron at my unstable, radioactive form (atomic number 235) and my nucleus splits with a roar of energy, firing neutrons in all directions and starting a chain reaction that rips me apart! Control this reaction (called nuclear fission) and I generate power, but pack me into a bomb, and I can flatten whole cities.

- Density 19.05 g/cm<sup>3</sup>
  - Melting point 1,132.2°C (2,070°F)
  - Boiling point 3,900°C (7,101°F)
- U

Date of discovery: 1789

# 93 Neptunium

## • The Actinoid Elements

✧ Symbol: Np

✧ Atomic number: 93

✧ Atomic weight: 237.05

✧ Color: Silvery metallic

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

As remote as the planet Neptune, I'm a mean radioactive menace. We're a nasty crew of tooled-up elements who take our gang names from the Solar System's super-cold far-off worlds—Uranus, Neptune, and Pluto. Sitting between the more famous uranium and plutonium, I am less well known and often forgotten about.

Discovered in 1940 at the University of California, Berkeley, I was the first artificially created element. I can occur naturally as a by-product of the radioactive breakdown of uranium, but this will only ever create vanishingly small amounts. I'm more commonly made as a waste product of nuclear reactors and, with a two-million-year half-life, I'm around and thoroughly nasty for a long time. I can substitute for either of my brothers in nuclear bombs, so I am a strictly controlled and heavily monitored substance.

Date of discovery: 1940

● Density 20.45 g/cm<sup>3</sup>

● Melting point 637°C (1,179°F)

● Boiling point 4,000°C (7,232°F)



Np



Neptunium



# 94 Plutonium

## The Actinoid Elements



✧ Symbol: Pu

✧ Atomic number: 94

✧ Atomic weight: 244.06

✧ Color: Silver-white

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

Unlike that Disney dog, life ain't no cartoon for me—I'm deadly serious. Made by nuclear scientists, a lump of me radiates heat because I release masses of radioactive alpha particles. In August 1945, a nuclear bomb made from my "239" isotope was dropped on Nagasaki in Japan. It killed or injured close to 200,000 people.



Plutonium

Date of discovery: 1940

Pu ● Density 19.816 g/cm<sup>3</sup>  
● Melting point 639.4°C (1,182.9°F)  
● Boiling point 3,230°C (5,846°F)



# Americium 95

## The Actinoid Elements

- ✧ Symbol: Am
- ✧ Atomic number: 95
- ✧ Atomic weight: 243.06

- ✧ Color: Silver-white
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic



I'm an all-American hero! Playing a key role in smoke alarms, I've saved countless people's lives from fire. I'm the only dangerous radioactive element allowed in your home—I had to get a special permit for it! Still, it takes less than a millionth of a gram to do the job. Sitting beneath europium on the periodic table, I'm named after America.

- Density 12 g/cm<sup>3</sup>
- Melting point 1,176°C (2,149°F)
- Boiling point 2,607°C (4,725°F)

Am

Date of discovery: 1789

# 96 Curium

## The Actinoid Elements



★ Symbol: Cm

★ Atomic number: 96

★ Atomic weight: 247.07

★ Color: Silvery

★ Standard state: Solid at 25°C (77°F)

★ Classification: Metallic

Don't mix me up with anything health-giving—I am another no-good radioactive element. Though I wish I could “curi-um” all, I'm more likely to kill 'em! I get my name from Marie and Pierre Curie. I have had some wild, out-of-this-world times in space probes, satellites, and warming chilly robot rovers on the planet Mars.



Date of discovery: 1944

Cm

- Density 13.51 g/cm<sup>3</sup>
- Melting point 1,340°C (2,444°F)
- Boiling point 3,110°C (5,630°F)



# Berkelium 97

## The Actinoid Elements

- ★ Symbol: Bk
- ★ Atomic number: 97
- ★ Atomic weight: 247.07

- ★ Color: Silvery
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Berkelium

A university scientist made me in the U.S. nuclear labs at Berkeley —just like americium, californium, and a good many others. I'm a self-made whiz kid and an all-around good egg. Like all "transuranium" elements (those heavier than uranium), I'm entirely manufactured. You won't find me on Earth, and I'm gone in a flash!

- Density 14.78 g/cm<sup>3</sup>
- Melting point 986°C (1,807°F)
- Boiling point unknown

Bk

Date of discovery: 1949

# 98 Californium

## The Actinoid Elements



✧ Symbol: Cf

✧ Atomic number: 98

✧ Atomic weight: 251.08

✧ Color: Silvery

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

Born in the Golden State, I'd love to be laid-back, but the problem is my chilling ability to release streams of neutrons from my atomic nucleus. My ferocious rays can pass through an object as if it weren't there, leaving everything in its path radioactive. My neutron beams are used to kick-start nuclear reactors and to detect oil and gold.



Date of discovery: 1950

Cf ● Density 15.1 g/cm<sup>3</sup>  
● Melting point 900°C (1,652°F)  
● Boiling point unknown





# Einsteinium 99

## The Actinoid Elements

- ★ Symbol: Es
- ★ Atomic number: 99
- ★ Atomic weight: 252.08
- ★ Color: Silvery
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Einsteinium

With my crazy looks, there's no mistaking that I'm named after the famous scientist Albert Einstein. I was created in the hellish furnace of the world's first thermonuclear bomb. In 1952, the "H" bomb exploded with the energy of ten million tons of TNT, obliterating a small South Pacific island. In among the debris, sat I, beaming with radiation.

- Density 13.5 g/cm<sup>3</sup>
- Melting point 860°C (1,580°F)
- Boiling point unknown

Es

Date of discovery: 1952



# 100 Fermium

## The Actinoid Elements

✧ Symbol: Fm

✧ Atomic number: 100

✧ Atomic weight: 257.10

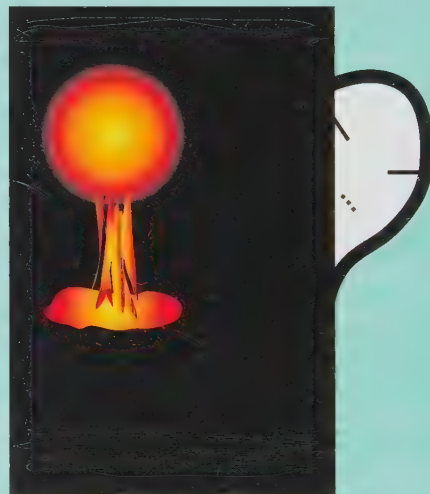
✧ Color: Unknown/silvery-gray

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I am the periodic table's "centurion," you can always trust me to give 100 percent. I am named after the scientist who made the first nuclear reactor, Enrico Fermi. Finding a new source of power was the initial step in the U.S. project to build the terrifying weapon that brought World War II to a swift and horrific end—the atomic bomb.

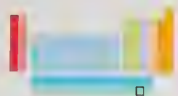
Date of discovery: 1952



## Fermium

Fm

● Density	unknown
● Melting point	1,527°C (2,781°F)
● Boiling point	unknown



# Mendelevium 101

## The Actinoid Elements

- ✧ Symbol: Md
- ✧ Atomic number: 101
- ✧ Atomic weight: 258.10
- ✧ Color: Unknown/silvery-gray
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic



Mendelevium

Hooray for me, the most important element! I must be, right? After all, I'm named after that meddling Professor Mendeleev, the father of the periodic table! I'm the first "transfermium" element (heavier than fermium). Super-super-rare, I'm made in batches of a half-dozen atoms at a time and mostly I'm good for nothing!

- Density unknown
- Melting point 827°C (1,521°F)
- Boiling point unknown

Date of discovery: 1955

Md

# 102 Nobelium

## The Actinoid Elements

✧ Symbol: No

✧ Atomic number: 102

✧ Atomic weight: 259.10

✧ Color: Unknown/metallic

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

I'm a true prizewinner!  
All of the dudes and  
dames who have had  
elements named after  
them have been great  
nuclear physicists making  
astounding discoveries...  
aside from me, that is.  
You see, I snuck in the  
back door, because I'm  
named after Alfred Nobel,  
who gave his name to the  
prize that has honored so  
many scientists.



Date of discovery: 1966

No

● Density unknown  
● Melting point 827°C (1,521°F)  
● Boiling point unknown



# Lawrencium 103

## The Actinoid Elements

- ★ Symbol: Lr
- ★ Atomic number: 103
- ★ Atomic weight: 262.11
- ★ Color: Unknown/silvery-gray
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Lawrencium

Pleased to meet you,  
please call me Lawrence.  
I'm the last of the actinoid  
elements—the long strip  
of superheavies at the  
bottom of the periodic  
table. I'm named after  
Ernest Lawrence, who  
built the very first  
“cyclotron” particle  
accelerators in which  
many of these new,  
unnatural elements  
are made.

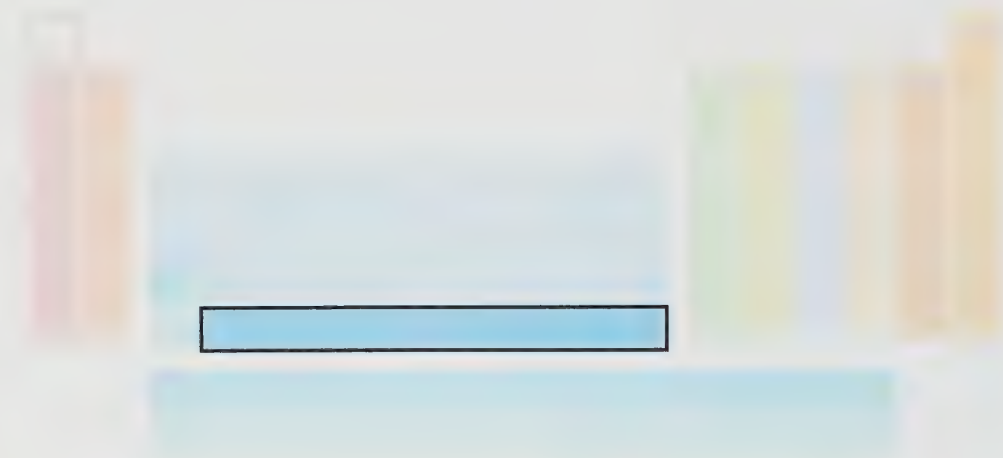
- Density unknown
- Melting point 1,627°C (2,961°F)
- Boiling point unknown

Lr

Date of discovery: 1961

# CHAPTER 12

## The Superheavies



This group is totally “out there.” Here at the far reaches of the periodic table live elements with atomic numbers greater than 103. These superheavy substances have all been artificially created in the lab, so most of them have only ever existed in minuscule amounts. Every single one is extremely radioactive and decays incredibly quickly. Many labs all around the world lay claim to having been the first to produce these elements, so there is always a great deal of healthy argument about what each element should be called.

104



Rf

RUTHERFORDIUM

105



Db

DUBNIUM

106



Sg

SEABORGIUM

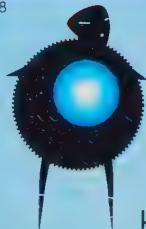
107



Bh

BOHRNIUM

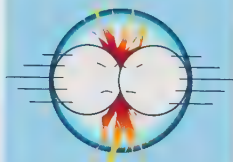
108



Hs

HASSIUM

109



Mt

MEITNERIUM

110



Ds

DARMSTADIUM

111



Rg

ROENTGENIUM

112



Cn

COPERNICIUM



# 104 Rutherfordium

## The Superheavies

- ✧ Symbol: Rf
- ✧ Atomic number: 104
- ✧ Atomic weight: 265.12
- ✧ Color: Unknown
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic

I'm the first of the "mayfly" superheavies. Entirely synthetic, we never occur in nature and don't hang around for long. Half of my atoms will have broken up within an hour. I may be quick, but it took people nearly 30 years to give me a name! After arguing about it, they settled on Ernest Rutherford, the New Zealand father of nuclear physics.



Date of discovery: 1969

Rf

- Density 17 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown



# Dubnium 105

The Superheavies ■

- ✧ Symbol: Db
- ✧ Atomic number: 105
- ✧ Atomic weight: 268.13
- ✧ Color: Unknown
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic



Dubnium

Rub-a-dub-dub, I'm a champ not a chump—the longest-lived of all the superheavyweights. With an average of 28 hours before my atom decays, there's plenty of time to do some chemistry on me. This places me firmly in Group 5, with tantalum, niobium, and vanadium. My name comes from the Russian lab in which I was first discovered.

- Density 21.6 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

Db

Date of discovery: 1968

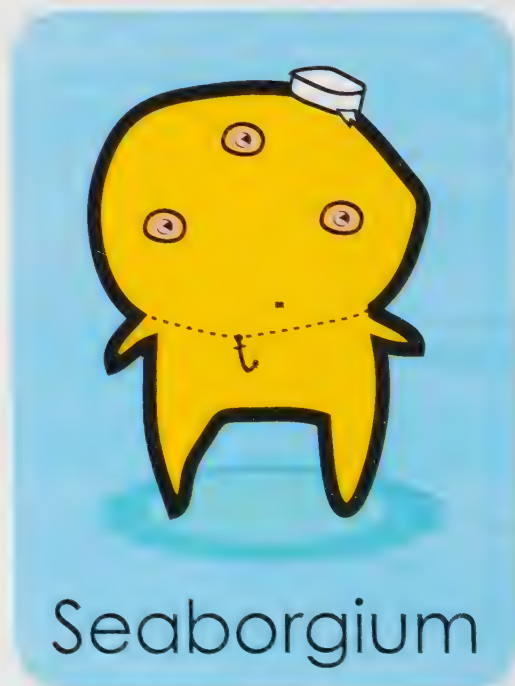
# 106 Seaborgium

## ■ The Superheavies

- ☼ Symbol: Sg
- ☼ Atomic number: 106
- ☼ Atomic weight: 271.13
- ☼ Color: Unknown
- ☼ Standard state: Solid at 25°C (77°F)
- ☼ Classification: Metallic

Along with the actinoid element, einsteinium, I'm the only element named after someone who was still alive at the time. . . so far! I take my sci-fi-sounding name from one Glenn T. Seaborg, who discovered ten elements in total, although I wasn't one of them! How weird is that? My most stable versions stick around for no more than two minutes.

Date of discovery: 1974



Sg • Density 23.2 g/cm<sup>3</sup>  
• Melting point unknown  
• Boiling point unknown

# Bohrium 107

The Superheavies ■

- ✧ Symbol: Bh
- ✧ Atomic number: 107
- ✧ Atomic weight: 270.13
- ✧ Color: Unknown
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic



The folks who first made me wanted to call me “nielsbohrium” to honor Danish nuclear physicist Niels Bohr. In the end, they settled on boring bohrium! Just like the rest of the here-today-gone-tomorrow superheavy crew, I’m made by smashing together lighter elements in a particle accelerator. Nothing “bohrium” about that!

- Density 27.2 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

Bh

Date of discovery: 1981

# 108 Hassium

■ The Superheavies

✧ Symbol: Hs

✧ Atomic number: 108

✧ Atomic weight: 277.15

✧ Color: Unknown

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

Zip! Ping! Ten seconds and I wink out of this world. Blink and you'll miss me! It's a little bit of a hassle to make me, but that's not where I get my name. I'm named after Hesse in Germany, where I was first made in 1984. It's just one of three places in the world with the equipment to make me and my pals. The others are Russia and the United States.

■ Date of discovery: 1984



Hs

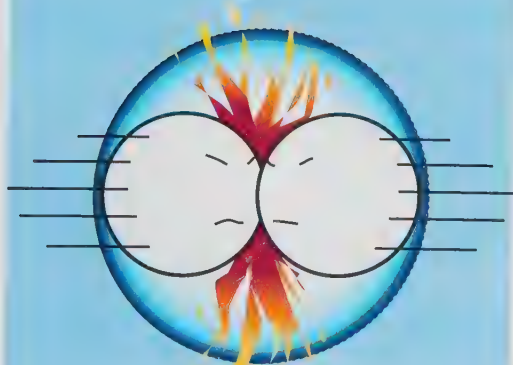
- Density 28.6 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown



# Meitnerium 109

The Superheavies

- ★ Symbol: Mt
- ★ Atomic number: 109
- ★ Atomic weight: 276.15
- ★ Color: Unknown
- ★ Standard state: Solid at 25°C (77°F)
- ★ Classification: Metallic



Meitnerium

Dressed all in white and with a half-life of less than a second, no chemical experiments have ever been done with me. I was named after the German physicist Lise Meitner. She discovered nuclear fission—the process that makes nuclear bombs possible—with Otto Hahn. He got the Nobel prize, so it's only fair that Lise should get the element!

- Density 28.2 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

Mt

Date of discovery: 1982



# 110 Darmstadtium

The Superheavies

✧ Symbol: Ds

✧ Atomic number: 110

✧ Atomic weight: 281.16

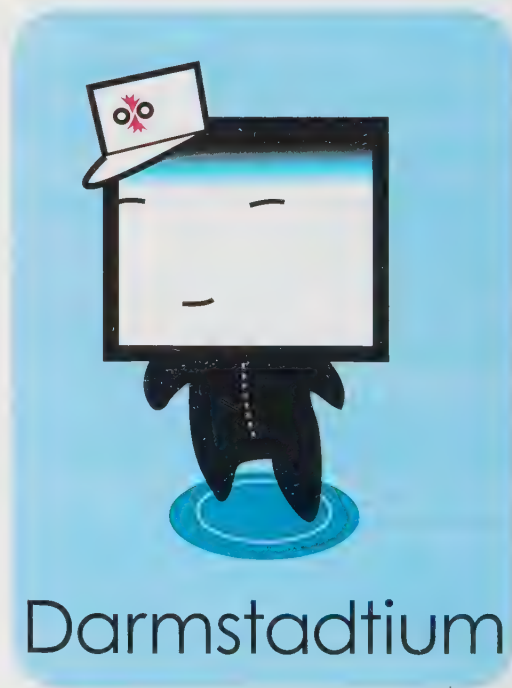
✧ Color: Unknown

✧ Standard state: Solid at 25°C (77°F)

✧ Classification: Metallic

Fresh-faced and real eager to please, I'm a child of the '90s. However, since you need to make a handful of atoms of me at a time (like the rest of my superheavy brothers and sisters), and most of my atoms are gone in the blink of an eye, there's very little that you can actually do with me. You see, all in all, I'm something of a fusspot!

Date of discovery: 1994



Ds ● Density 27.4 g/cm<sup>3</sup>  
● Melting point unknown  
● Boiling point unknown



# Roentgenium 111

The Superheavies

- ✧ Symbol: Rg
- ✧ Atomic number: 111
- ✧ Atomic weight: 280.16
- ✧ Color: Unknown
- ✧ Standard state: Solid at 25°C (77°F)
- ✧ Classification: Metallic



Roentgenium

I live life in the fast lane and love to keep the best company. I am the heaviest and newest member of the prestigious group of elements that contains copper, silver, and gold. With a half-life of around 20 seconds and only a handful of atoms of me ever having existed, I'm super-super-rare. Yep, you can call me a precious metal!

- Density 24.4 g/cm<sup>3</sup>
- Melting point unknown
- Boiling point unknown

Rg

Date of discovery: 1994

# 112 Copernicium

## ■ The Superheavies

✧ Symbol: Cn

✧ Color: Unknown

✧ Atomic number: 112

✧ Standard state: Liquid at 25°C (77°F)

✧ Atomic weight: 285.17

✧ Classification: Metallic

Artificially created in 1996, I am the last transition element. My birthplace is a famous research center in Darmstadt, Germany. I winked into existence when scientists bombarded a lead target with a beam of zinc ions.

Only about 75 atoms of my element have ever existed and, until recently, I decayed radioactively, disappearing in a millisecond. My current most stable isotope (cn-285) sticks around for 29 seconds! I hope they'll find a version of me that lasts a bit longer, so that I can be studied. There's a chance that I'm liquid at room temperature, like mercury, which would make me the second liquid metal known to science. It's enough to put your head in a whirl, which might explain why I was named after the astronomer Copernicus. He put the Sun at the center of the Solar System with the planets spinning around it.

Date of discovery: 1996

● Density 16.8 g/cm<sup>3</sup>

● Melting point unknown

● Boiling point unknown



Cn



Copernicium

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# GLOSSARY

**Alchemy** Medieval attempts to convert base metals into gold.

**Alloy** A mixture of metals.

**Alpha particle** A positively charged particle (a helium nucleus) given off during some types of radioactive decay.

**Atom** The fundamental building block of all matter.

**Beta particle** A negatively charged particle (an electron) given off during some types of radioactive decay.

**Catalyst** A substance that speeds up a chemical reaction.

**Compound** A substance created by the chemical bonding of elements.

**Electron** A subatomic particle with a negative charge.

**Element** A substance that cannot be further broken down by chemical reactions.

**Gamma ray** High-energy electromagnetic radiation given off by some nuclei.

**Group** A vertical column of elements on the periodic table.

These elements often have closely related properties.

**Ion** A charged particle formed when an atom loses or gains electrons.

**Ionization** The process of producing ions.

**Isotope** Atoms of the same element that have the same number of protons and electrons but differing numbers of neutrons.

**Neutron** A subatomic particle with a neutral charge.

**Nucleus** The center of an atom where protons and neutrons are found.

**Oxide** A compound of one element with oxygen.

**Particle accelerator** A machine that can produce new elements by colliding charged particles at high speeds.

**Period** A horizontal row of elements on the periodic table.

**Proton** A subatomic particle with a positive charge.

**Radioactivity** The spontaneous disintegration of certain nuclei accompanied by the emission of alpha, beta, or gamma radiation.

**Salts** Compounds formed when the hydrogen ions in an acid are replaced by metal ions or other positive ions.





Do you confuse boron with barium, or  
with fluorine? Do you know which  
elements are in your cellphone battery  
and in giant wind turbines?

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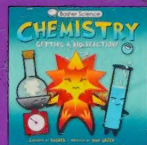
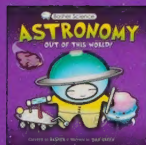
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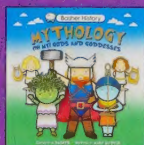
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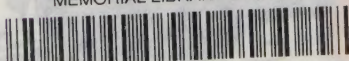
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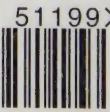


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