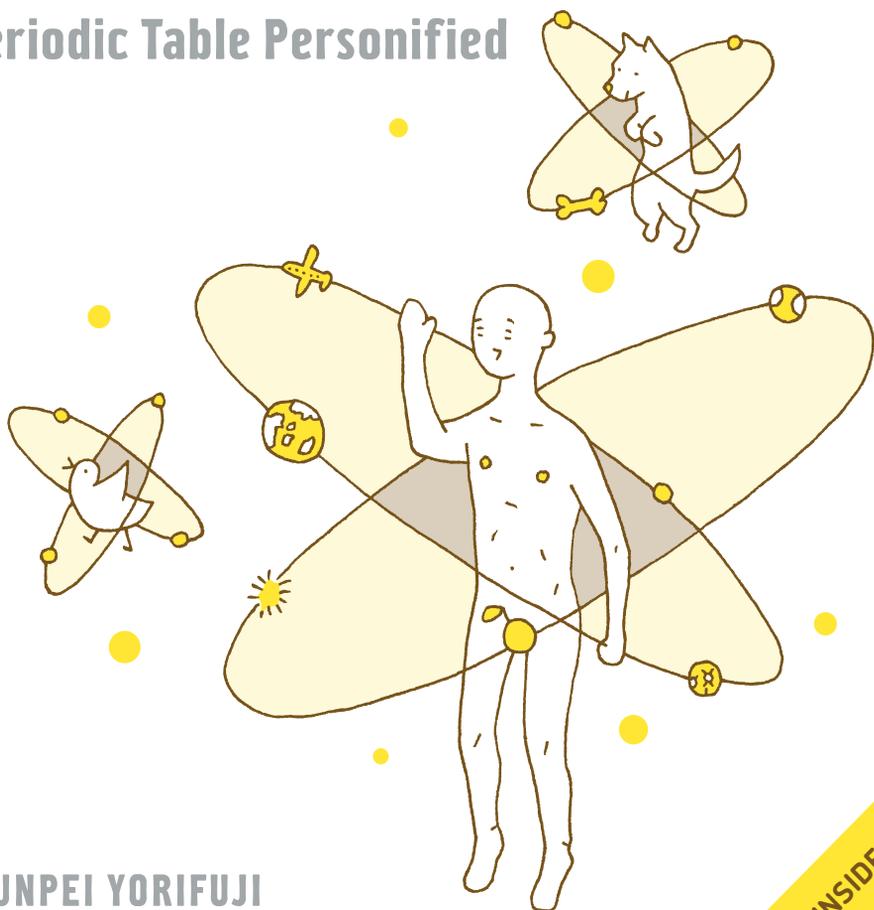


Wonderful Life with the Elements

The Periodic Table Personified



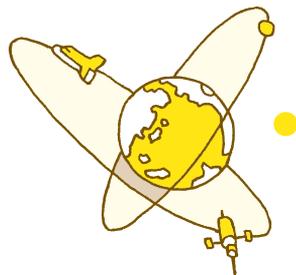
BUNPEI YORIFUJI

POSTER INSIDE!

Wonderful Life with the Elements

The Periodic Table Personified

by Bunpei Yorifuji



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PREFACE

Do you know what happens if you inhale a lot of helium? Back when I was an art student, I bought two canisters of pure helium for one of my works. Inhaling helium, as you might know, raises the pitch of your voice. But common helium balloons don't really raise your voice that much, and it goes back to normal right away.

“BUT I MIGHT BE ABLE TO PRODUCE SOME REALLY FUNKY NOISES WITH THESE.”

So I exhaled with all my might, opened one of the canisters, and filled my lungs with as much helium as I could. And everything just went black. I tried to breathe, but all I could really do was gasp, as no air would grace my lungs. I could feel the warmth leaving my body as I started to lose consciousness. It was only after this experience that I learned that inhaling pure helium can lead to suffocation and death.

Since I was all alone in the lab, I decided it might be a good idea to call out for help.

IN SUPER SOPRANO: “HELP MEEE....”

But that voice! Inhaling helium is dangerous in more than one way. The first is that it suffocates you, and the second is that even if you call for help, your cries will probably be dismissed as a bad practical joke.



We're usually not aware of the elements in our daily lives. We don't look at a desk and instantly think "Carbon!" And knowing a lot about the elements doesn't really make you cool (in fact it's quite the opposite).

THE CONCEPT OF ELEMENTS DOESN'T COME NATURALLY TO US.

First of all, protons, neutrons, and electrons are all so small. And the idea that you can split this complex world into 118 basic elements isn't easy to believe. But the concept of the elements also has this aura of serenity that is hard to resist—a promise that hints at the true core of all matter. However, they are still too small to for us to care about in our daily lives, and they're too abstract to serve as explanations for why the things around us are as they are.

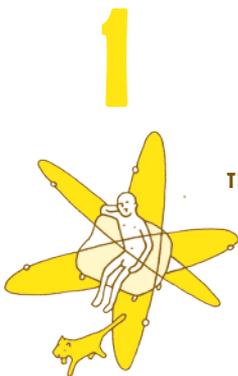
In this book, I've tried to distill these seemingly abstract little things into something that might be easier to grasp. This book was written with the help and supervision of Kouhei Tamao of the Institute of Physical and Chemical Research, Hiromu Sakurai of Kyoto Pharmaceutical University, and Takahito Terashima of Kyoto University. I don't think there is any real point in trying to remember everything about every element, but I hope that you'll learn a little about each and every one of them—and have fun—by reading this book.

Help meee...



surprised at
his own voice

but it went back to
normal right away.

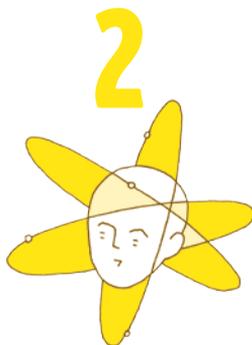


リビングと元素
ELEMENTS IN THE LIVING ROOM

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PREFACE
まえがき

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THE SUPER PERIODIC TABLE OF THE ELEMENTS

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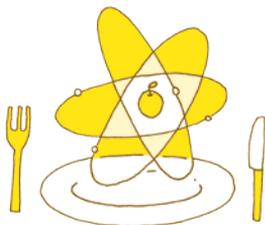
元素キャラクター
ELEMENT CARTOON CHARACTERS

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PERIOD 1, 2, 3	1 - 18	p.062
PERIOD 4	19 - 36	p.086
PERIOD 5	37 - 54	p.110
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元素の食べ方

HOW TO EAT THE ELEMENTS

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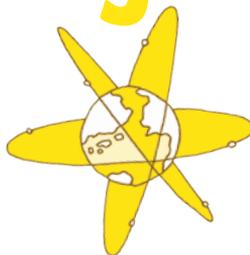
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元素危機

THE ELEMENTS CRISIS

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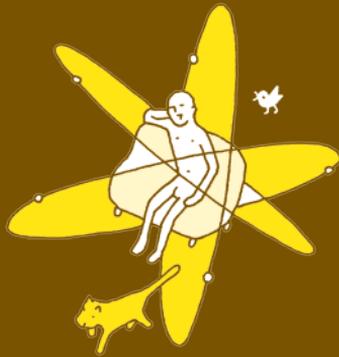
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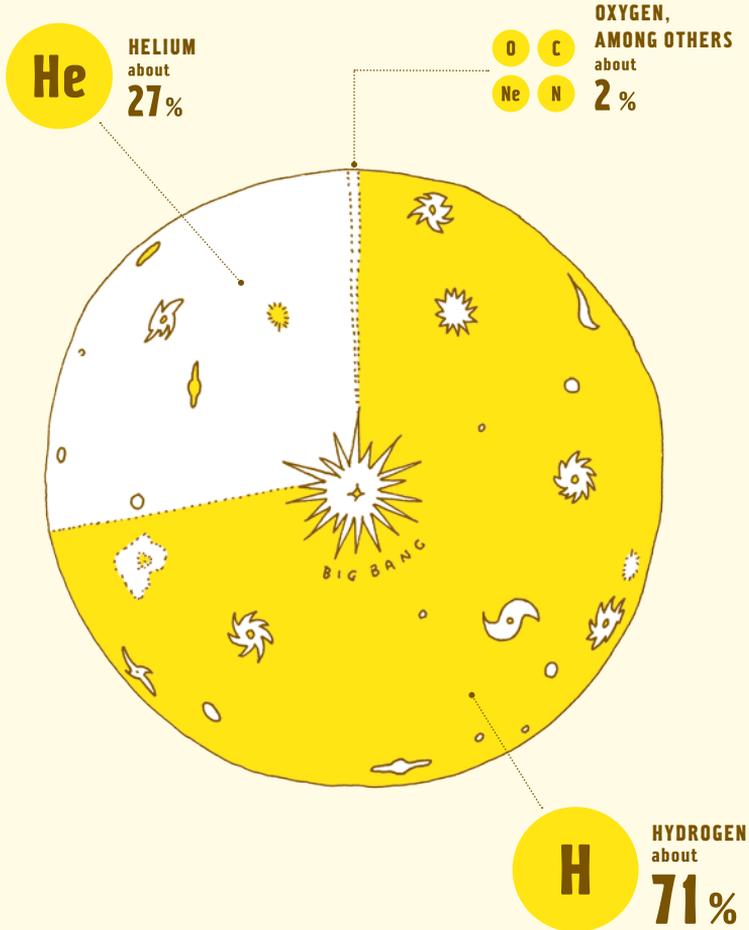


ELEMENTS IN THE LIVING ROOM

リビングと元素

宇宙を構成する元素

ELEMENTS OF THE UNIVERSE



太陽を構成する元素

ELEMENTS OF THE SUN

HELIUM
about
4.8%

He

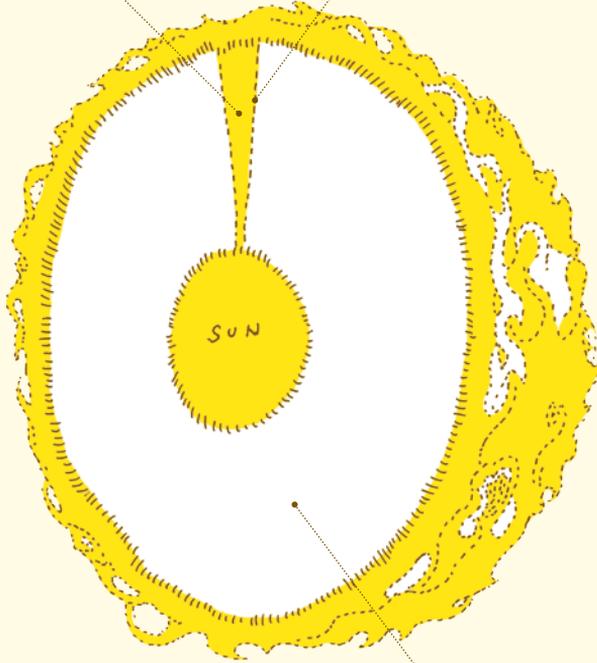
O

C

Ne

N

OXYGEN,
AMONG OTHERS
about
0.1%



H

HYDROGEN
about
95.1%

地球を構成する元素

ELEMENTS OF EARTH

CARBON,
AMONG OTHERS
about
8.0%



IRON
about
34.6%

Fe

Mg

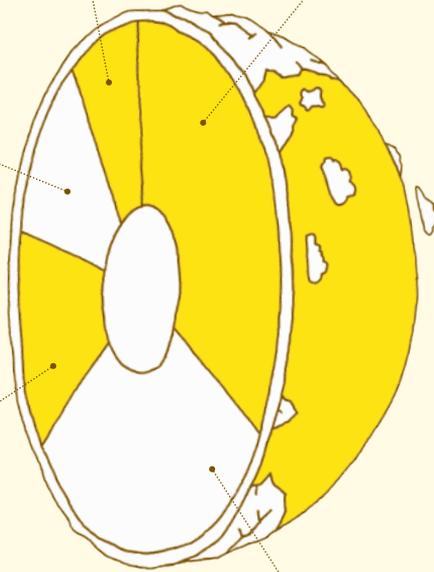
MAGNESIUM
about
12.7%

Si

SILICON
about
15.2%

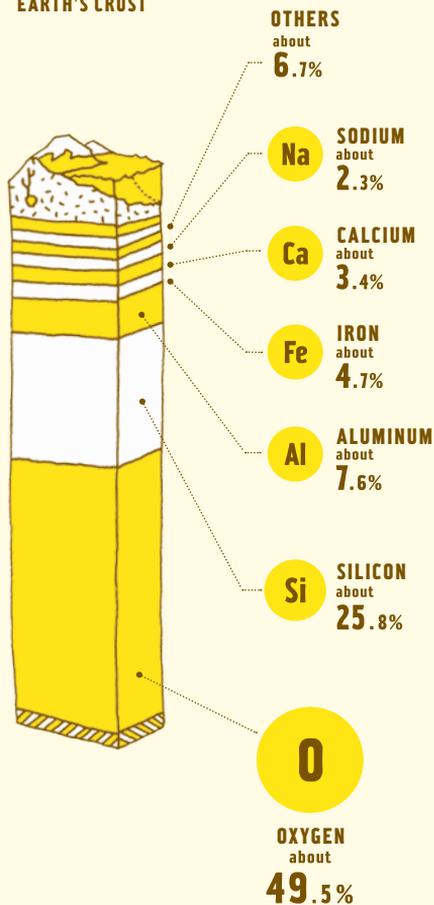
O

OXYGEN
about
29.5%



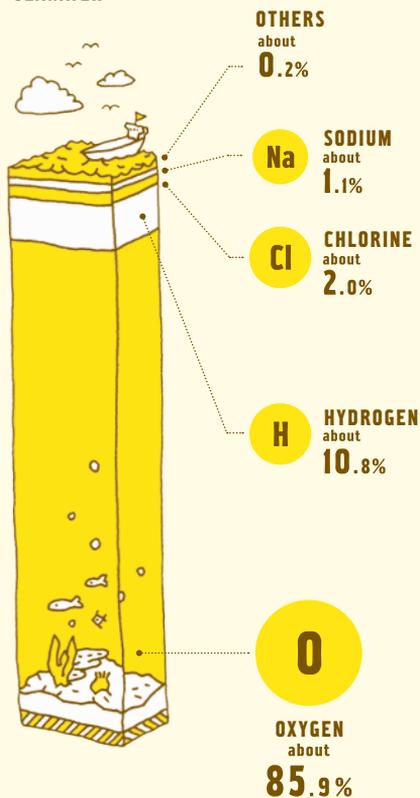
地殻を 構成する元素

ELEMENTS OF EARTH'S CRUST



海水を 構成する元素

ELEMENTS OF SEAWATER

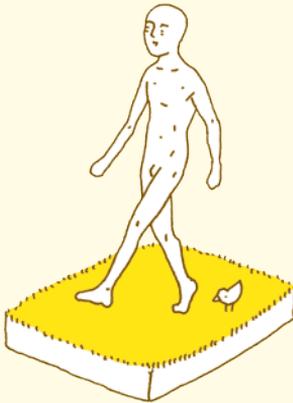


Elements fit perfectly in discussions of things like planets and outer space. But discussing our daily lives from the perspective of elements usually doesn't make much sense. In the last billion years or so, the elements of Earth haven't changed much. And it doesn't matter to the elements whether people live or die—it's all the same to them.

ENVIRONMENTAL PROBLEMS DON'T AFFECT THEM EITHER.

The elements remain unaffected even if holes open up in the ozone layer or the atmosphere fills up with carbon dioxide. Unless something really drastic happens, like a meteor strike or a nuclear bomb, there's really no change to the elements of Earth. But if something like that happens, then nothing really matters anymore, does it? It becomes hard to even start comparing our daily lives to the lives of the elements when we think about it like this.

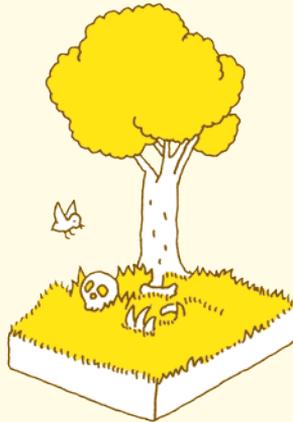
But even though there's no change in the elements themselves, if we look at a time span of say 10,000 years, a change in the way we use the elements can clearly be seen. Let's take a look at that next.



LIVE

生きている

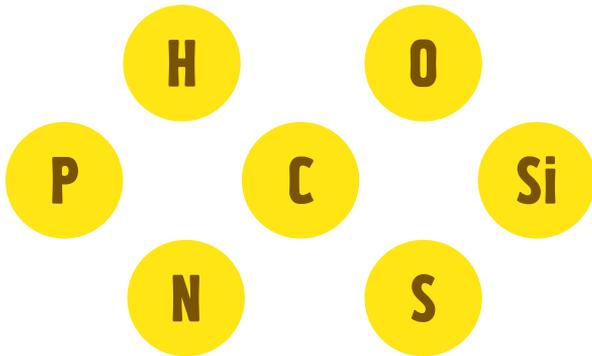
=



DEAD

死んでいる

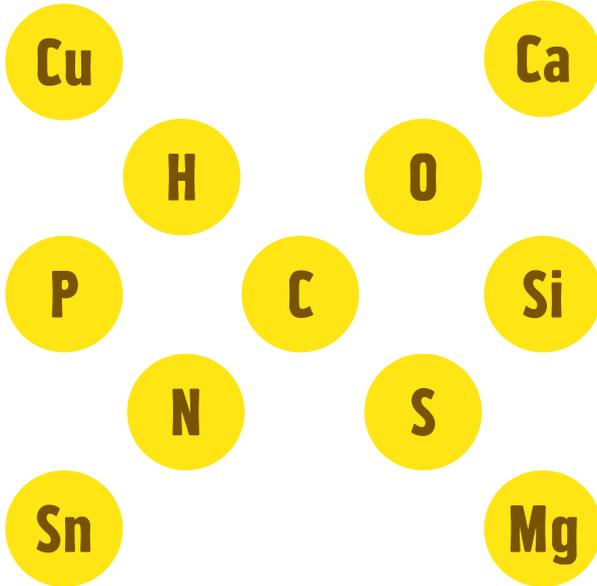
No change





原始の生活

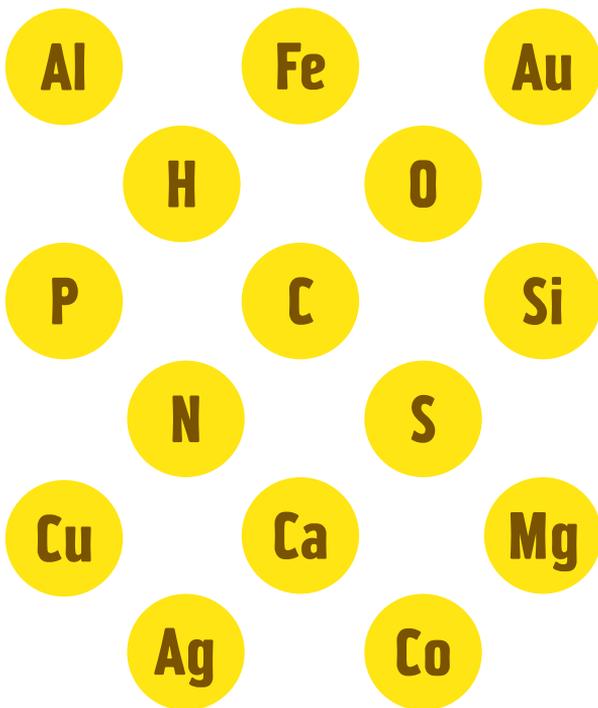
PRIMITIVE TIMES

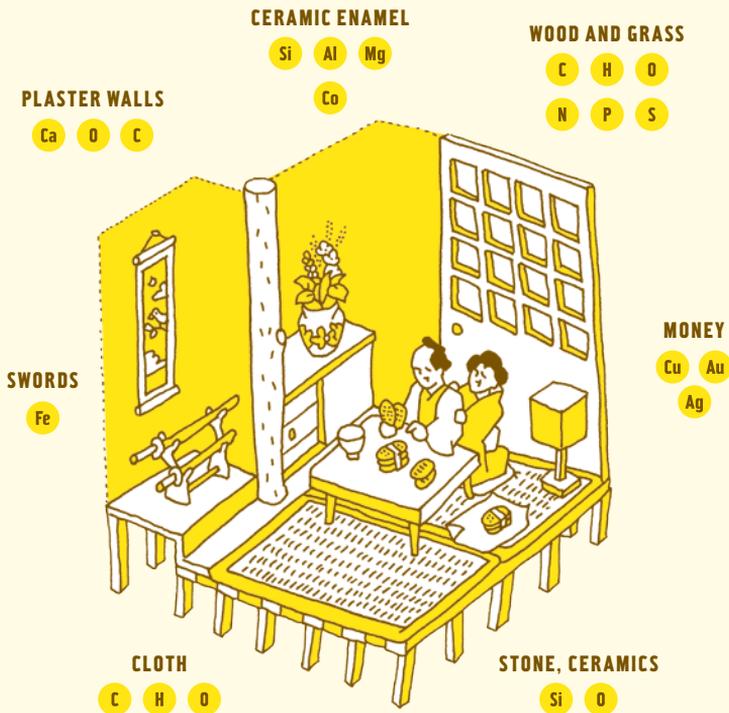




古代の生活

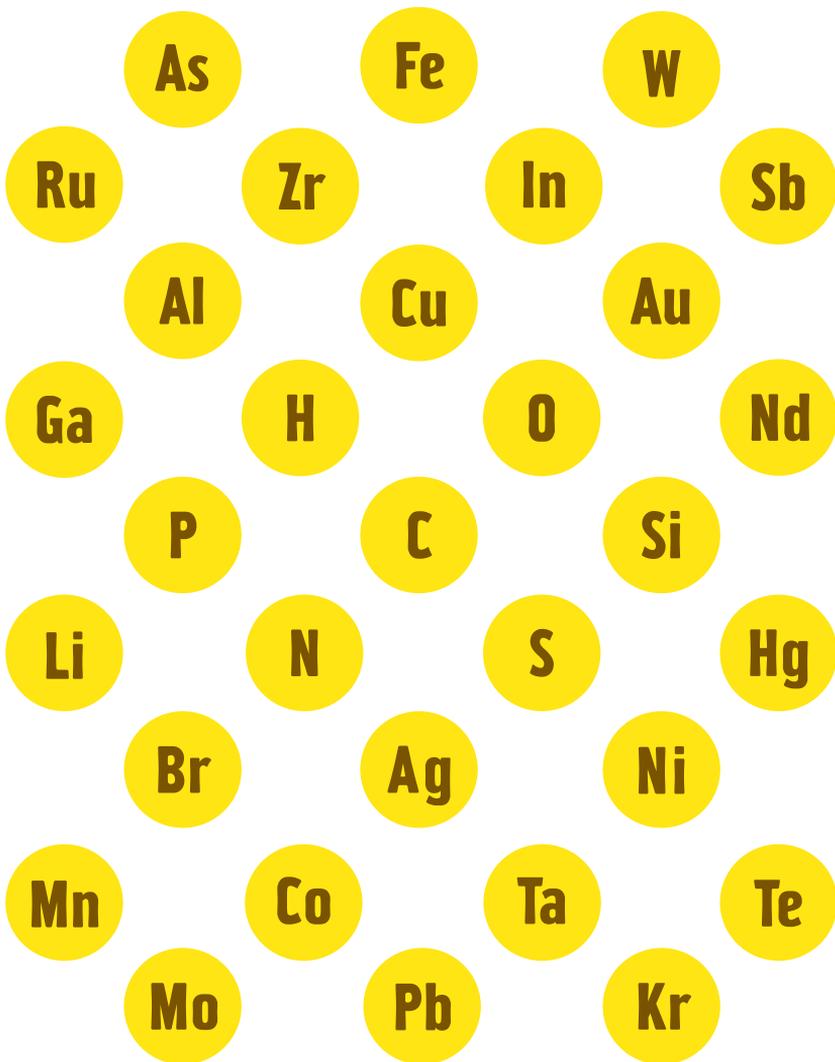
ANCIENT TIMES





中世の生活

MEDIEVAL TIMES

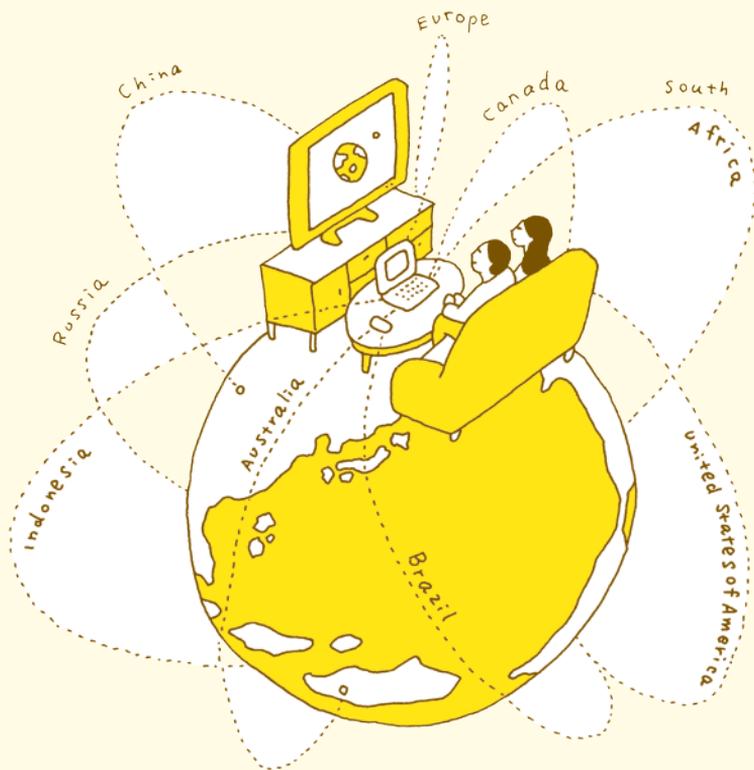


The number of elements we use every day has been steadily increasing over the last 10,000 years, with an especially sharp increase over the last 50 years or so. We use five times more elements than in primitive times and twice as many as in medieval times.

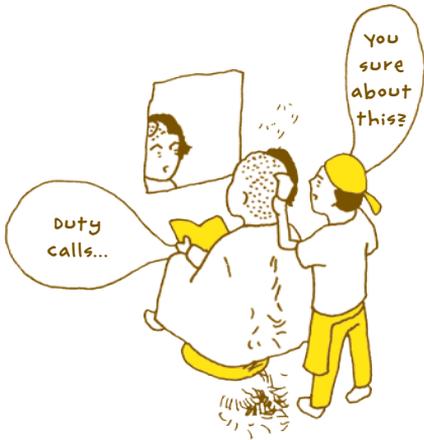
ELEMENTS FROM ALL CORNERS OF THE WORLD GATHER IN OUR LIVING ROOMS.

The indium used in our LCD TVs is from China, and plastic and vinyl are from oil drilled in the Middle East. (Oil is made up of carbon, mind you.) With the recent spread of the Internet, our borders have opened up with the help of copper and silicon dioxide (the elements that make up fiber-optic cables). Just imagine all the photons and electrons flying around the world. It probably wouldn't be a lie to say that this is the first time since the last cataclysmic asteroid struck Earth that this many different elements are being used at the same time.

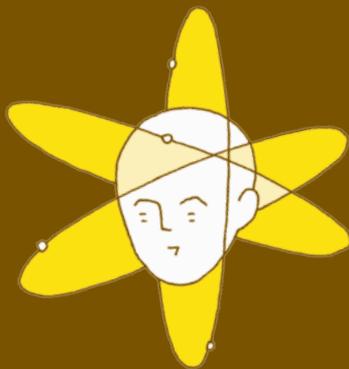
When we say “global,” most people think of the economy, or maybe politics. But there is probably nothing as “global” as the basic elements. We are always connected to the rest of the world through the elements in our technology.



The elements of
the world in
your living room



2



THE SUPER PERIODIC TABLE
OF THE ELEMENTS

スーパー元素周期表

元素周期表

THE PERIODIC TABLE OF THE ELEMENTS

Basic elements are usually represented using letters, like *F* and *H*. The rows in the table are called *periods*, and the columns are called *families* or *groups*. Since there are so many elements in both the Ln and An families, they've been given their own space at the bottom. Understanding the structure of the periodic table can really help when trying to learn about the amazing world of the elements.

1	H								
2	Li	Be							
3	Na	Mg							
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh
6	Cs	Ba	Ln	Hf	Ta	W	Re	Os	Ir
7	Fr	Ra	An	Rf	Db	Sg	Bh	Hs	Mt
PERIOD FAMILY	1	2	3	4	5	6	7	8	9
		Ln =	La	Ce	Pr	Nd	Pm	Sm	Eu
		An =	Ac	Th	Pa	U	Np	Pu	Am

								He
			B	C	N	O	F	Ne
			Al	Si	P	S	Cl	Ar
Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo
10	11	12	13	14	15	16	17	18
Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
Cm	Bk	Cf	Es	Fm	Md	No	Lr	

HARRIET LIKES NAVY KARL'S RUBBER-COATED FRIGATE.

I'm sure many of you used nonsensical mnemonic tricks like this one to memorize the periodic table just like I did.

This is a pointless waste of time.

The elements were originally arranged in this way according to the number of protons present in the atomic core, but this number also determines the number of electrons orbiting the core, and this number in turn determines the behavior of the atom, which finally determines the atom's properties. "Harriet Likes Navy Karl's..." is only a simple memorization tool to help you learn the elements' names; it doesn't help you actually get to know them.

That's why we have the periodic table.

The periodic table is the amazing result of many scientists' knowledge and hard work. But even so, it doesn't make much sense the first time you see it. By making each element's properties obvious at a glance, I've created a periodic table that should be a bit more accessible to newcomers.



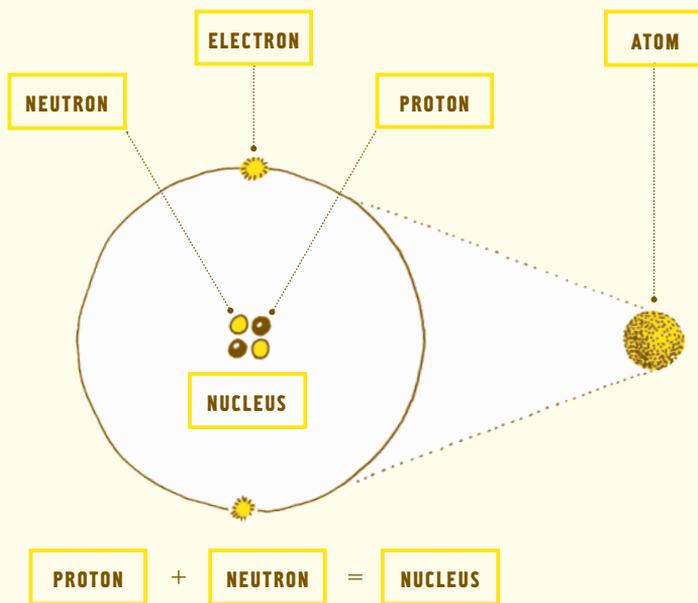
my hero!

This is no help at all...



通常の原子の表し方

ELEMENTARY PARTICLE NAMES



Atomic names are used to classify the basic elements.

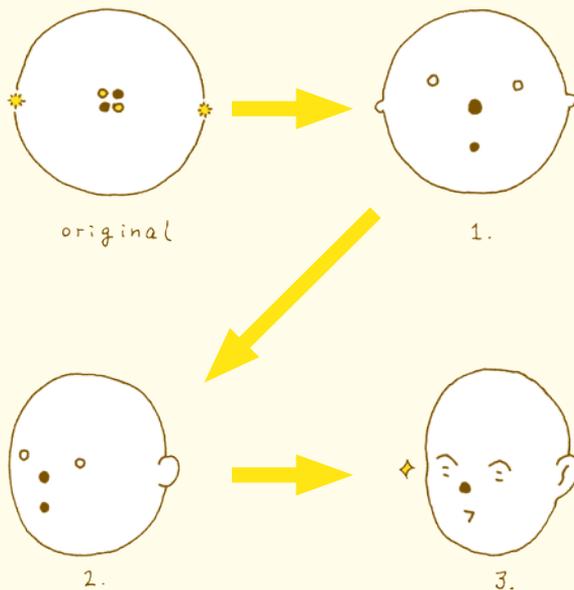
Atoms are made up of a nucleus and orbiting electrons. The nucleus consists of two kinds of particles called *protons* and *neutrons*.

Protons and electrons are electrically charged; protons are positive and electrons are negative. An atom in its most basic form is electrically balanced, which means that there is an equal number of protons and electrons. If additional electrons are added or removed, we say that the atom becomes *ionized*, and it is consequently called an *ion*.

The electrons orbiting the nucleus move very fast and are therefore collectively called the *electron cloud*. I simplified the cloud in the drawing above so that individual electrons can be seen.

原子を顔で表す

THE ATOM AS A FACE

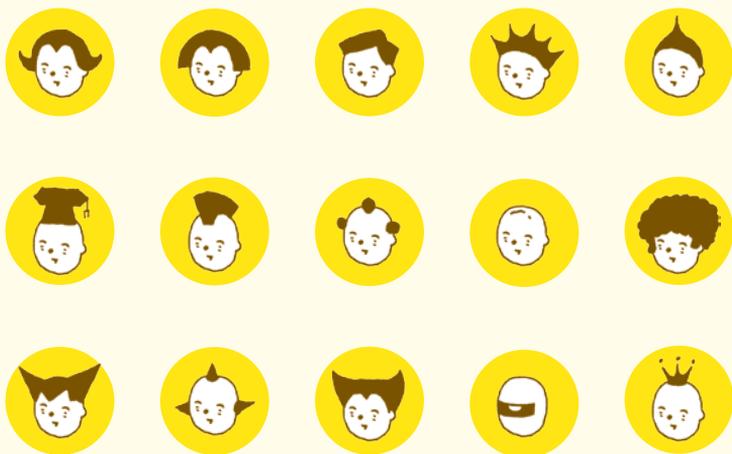


Each electron belongs to an electron shell. As the number of electrons increases, new shells are formed farther away from the nucleus. The electrons belonging to the outer shell are called *valence electrons*. Interactions between atoms are governed by their valence electrons, and many atomic properties are derived from the number of these electrons.

As you can see, I rearranged this atom into a face: The neutrons became eyes, and the protons became the nose and mouth. While not exactly scientific, this presentation should make for a much more attractive collection of elements.

元素のヘアスタイル

Hairstyles of the elements



I've split the properties of the elements into 14 categories. (Hydrogen is in a class by itself.) They're mostly organized according to the families in the periodic table, but since some elements belonging to the same family exhibit different properties and elements of different families can be similar, I decided to alter these categorizations slightly. I tried to model each group's hairstyle after its chemical properties.

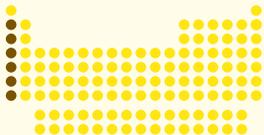


アルカリ金属

Alkali metals

Floaty, flirty hair.

All elements of the 1st family except hydrogen. They're very soft for being metals and can even be cut with a knife. They're also not very dense, so they float in water. And they oxidize easily, which means they quickly lose their luster.

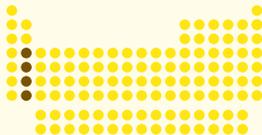


アルカリ土類金属

Alkaline earth metals

**A bit plain.
Pudding bowl cut.**

The metals belonging to the family in the lower part of the 2nd column from the left. They're highly reactive and can bind to the oxygen and moisture in the air, although not as easily as the alkali metals. They're commonly found in rock, hence the "earth" in the family name.



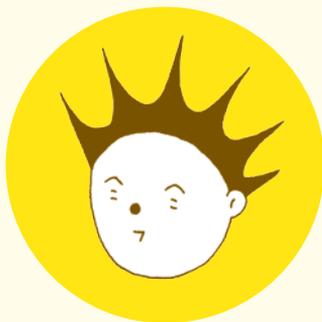


遷移金属

Transition metals

**The majority of the metal elements.
Clean-cut and boring.**

The elements from the 3rd to the 11th families. These are the multitude of elements usually referred to as *metals*. They all possess very similar properties, and there are a lot of them.



亜鉛族

The zinc family

**Volatile.
Punk hair.**

The four elements of the 12th family. Mercury is different from zinc and cadmium in that it's the only metal that's in liquid form at room temperature. These elements all evaporate easily, have low melting points, and are volatile.



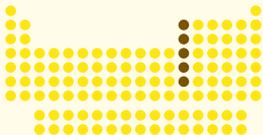


ホウ素族

The boron family

**Light and sharp.
Pointy hair.**

The elements of the 13th family. Aluminum is their front man, appearing in many modern applications. The family's name might rhyme with "moron," but don't underestimate these elements—gallium, indium, and the rest of them are all used in cutting-edge technology.



炭素族

The carbon family

**The talented ones.
Intellihair.**

The elements of the 14th family. Carbon is highly reactive, which means it will bind with many different elements and can be found in almost all organic compounds. Silicon is widely used as a semiconductor. Lead, germanium, and tin were very popular back in the day but don't make many appearances nowadays.



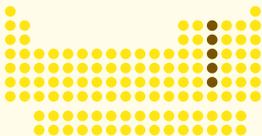


窒素族

The nitrogen family

**Hates normal.
Mohawk.**

The five elements in the 15th family. All of them are solids at room temperature except for nitrogen, which creates very stable molecules that make up about 80% of our atmosphere. Many of these have been known for ages, among them phosphorus and arsenic, which made good poisons among other things.

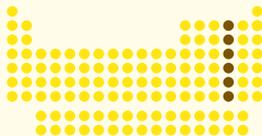


酸素族

The oxygen family

**Old school.
The half-assed bald shave.**

The 16th family, consisting of six elements. Oxygen is the only gas at room temperature. Sulfur, selenium, and tellurium are all ores and minerals that make up common rocks. Polonium is slightly radioactive. This group is often referred to as the *chalcogens*.





ハロゲン

Halogens

**Bald and bulbous,
like a halogen lamp.**

The nonmetallic elements of the 17th family. At room temperature, fluorine and chlorine are gases, iodine and astatine are solids, and bromine's a liquid, so they're not very similar in that respect. But they're all highly reactive and create salts when bound to elements from the alkali and alkaline earth families.



希ガス

Noble gases

**Too cool.
Afro.**

The six elements of the 18th family. They're the most stable elements of all and therefore seldom react. They all have low boiling and melting points. Helium doesn't solidify even at absolute zero (-273.15°C).



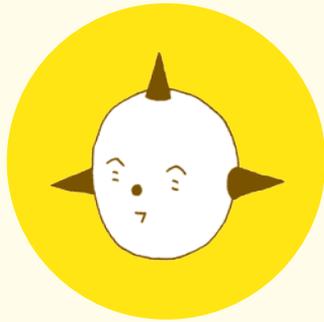


ランタノイド

Lanthanides

**Very rare.
Astro hair.**

The 15 elements starting with lanthanum and ending with lutetium. They are extremely rare and are therefore sometimes called the rare-earth elements. Some of them possess very similar properties and can be difficult to tell apart. It took over 100 years to find them all.



アクチノイド

Actinides

**Mostly man-made.
Robot hair.**

Actinides is the umbrella name for the 15 elements starting with actinium and ending with lawrencium. Their properties are very similar to the lanthanides series', and almost all of them are man-made. The elements after neptunium are all heavier than uranium, so they're sometimes called *transuranic*.



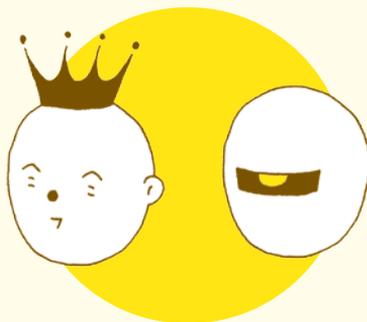


その他

Other metals

**The outsiders.
Weird hair.**

Beryllium and magnesium are in the same column as the alkaline earth metals, but I've decided to put them into their own category since they don't display some of the characteristics common to the others. For instance, they don't burn with any particular color when subjected to the flame test, while the other four do.



特別枠

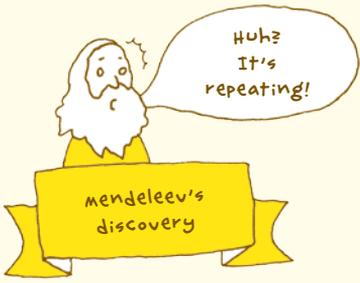
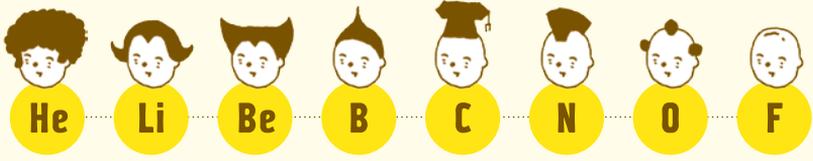
Hydrogen and the Unun series

**The supreme ruler
and the shrouded unknowns.**

Hydrogen holds a special place in the universe, as it's the simplest element of them all but makes up roughly 71% of the known universe. The properties of the hard-to-remember unun series in the other corner of the table, however, are still more or less unknown.

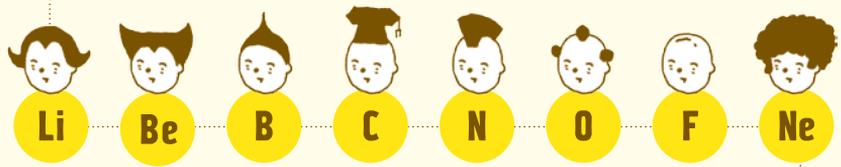


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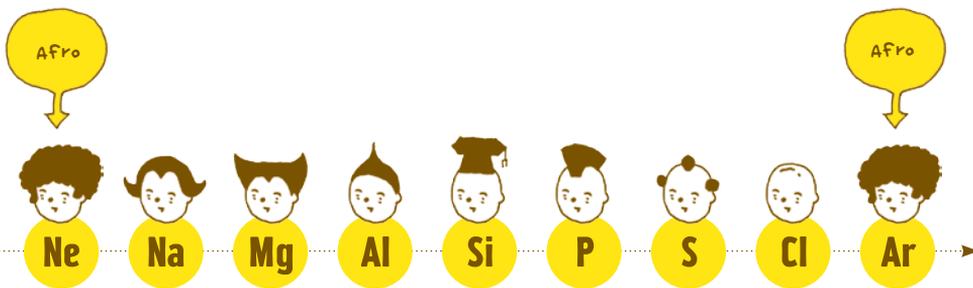


IF YOU FOLD IT UP...

Afro



IT BECOMES THE PERIODIC TABLE!



Now that we've split the elements into categories, let's line them up and look for a pattern. Do you see it?

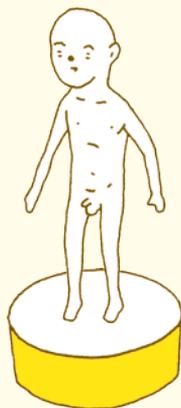
The elements, if arranged according to their atomic weight, exhibit an apparent periodicity of properties.

This is what the Russian scientist Dmitri Mendeleev discovered and wrote in his presentation "The dependence between the properties of the atomic weights of the elements." He pointed out that this periodicity can be used to create a table where elements of the same column exhibit similar properties, and get heavier with each row. This discovery eventually matured into the periodic table we know today.

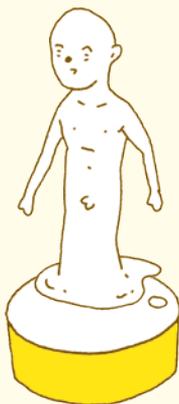
Just because we managed to split the elements into different categories doesn't mean that they don't have their individual quirks and properties. Wouldn't it be great if we could make a periodic table where you could see all these properties right away, just by looking at each element? Something like a *super* periodic table of the elements...

固体・液体・気体をカラダで。

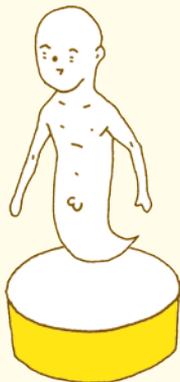
Matter states as body types



SOLID



LIQUID



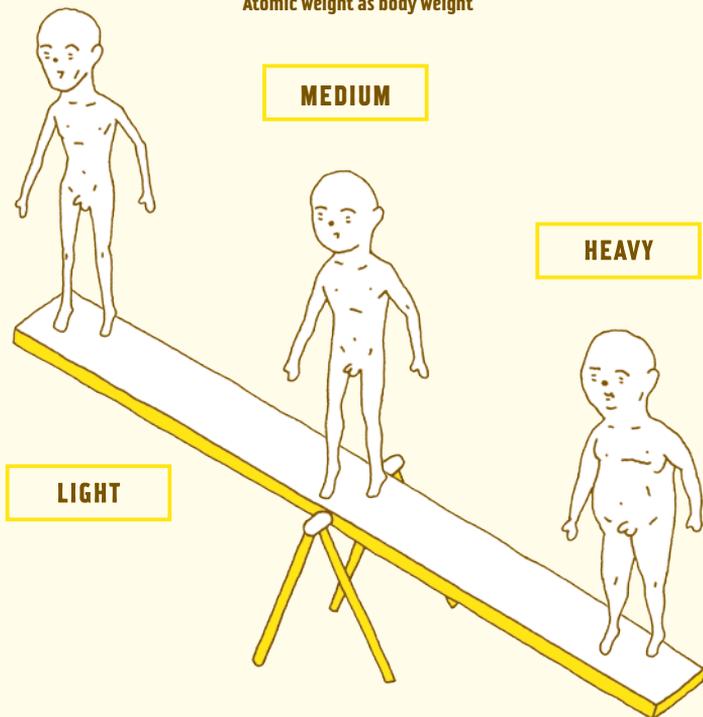
GAS

Let's not stop at faces. Let's do their bodies too!

At room temperature, some elements (like iron) are solid, others (like mercury) are liquid, and yet others (like oxygen) are gaseous. I'm going to let the lower half of their bodies indicate which form they normally have. Gases will be ghosts, liquids will be aliens from Planet X, and solids will be humans. There are only two natural liquids though, so most of them will be solids or gases.

原子量を体重で。

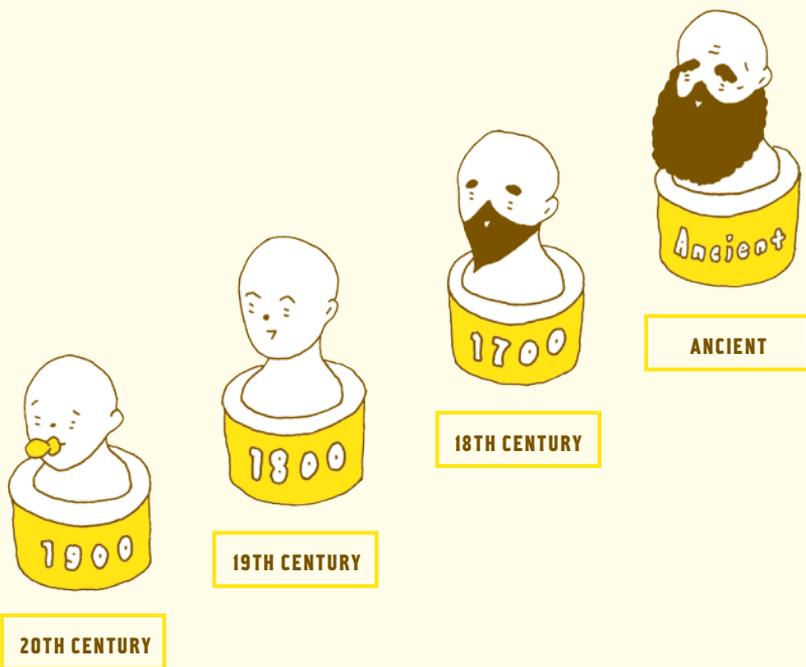
Atomic weight as body weight



One *atomic weight unit* is equal to one-twelfth of a carbon-12 atom's weight—but let's leave the technical stuff for another time. As you can see, I decided to model atomic weight as body weight. Atoms generally get heavier the farther you go in the periodic table, so my drawings will just keep getting fatter. It is worth noting that roentgenium (atomic number 111) is about 270 times as heavy as the lightest element, hydrogen. So instead of trying to model the exact relationships between the atoms, which would force me to draw the biggest elements several pages large, I'll just try to capture the general feeling of their relative sizes.

発見された年を年齢で。

Discovery year as age

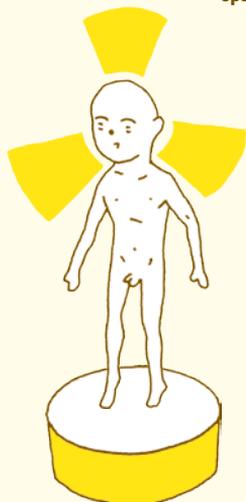


Some elements were discovered ages ago, and some synthetic ones were discovered only recently.

I thought I'd model their ages after how long we've known about them. Most elements were discovered during the 19th century, so using that as a baseline, I decided on these four simple categories.

特殊な性質は背景や服で。

Special properties as backgrounds and clothes



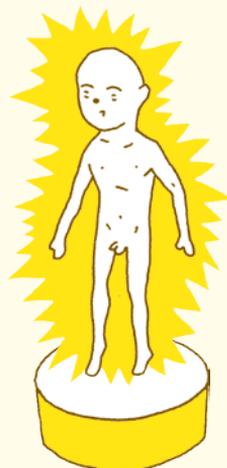
RADIOACTIVE

Radioactive elements. They can be difficult to handle but have many important uses.



MAGNETIC

Elements that generate powerful magnetic fields. I decided on a fancy two-tone suit to match the duality of a magnet's north and south poles.



LUMINESCENT

Elements used for luminous paint, fireworks, and fiber-optic cables.

I tried to make it extra clear which elements possess radioactive, magnetic, and luminescent properties. The mark around the radioactive character is inspired by the real radioactivity hazard symbol, which warns of alpha, beta, and gamma radiation.

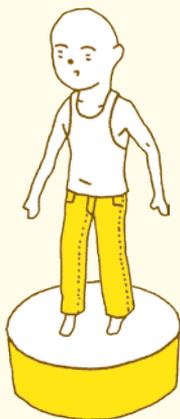
Magnetic elements will be easily recognized by their two-color suits.



The real mark looks like this.

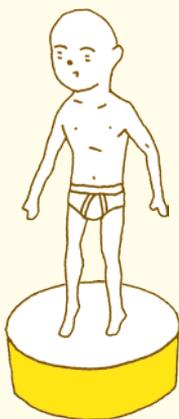
おもな使用用途を服装で。

Usage areas as clothes



MULTIPURPOSE

These versatile team players are popular in most application areas.



MINERAL

Elements used by our bodies as nutrients are dressed to show off their healthy physique.



DAILY

The nurturing materials we encounter every day in our kitchens and living rooms.



INDUSTRIAL

The businessman elements that work in our industries and factories.

Some elements are used by all of us, and some are used only by scientists. I decided to illustrate their applications by giving them different clothes, but it proved more difficult than I first anticipated. Some elements are used in many different areas, which makes it hard to say that they belong to any single one. But the categories should serve as a general pointer at least.



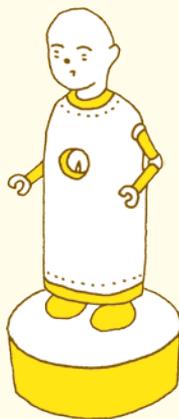
SPECIALIST

Elements used only in specialized applications wear coveralls.



SCIENTIFIC

Elements not yet used by the general public but that can be found in research laboratories wear lab coats.



MAN-MADE

Man-made elements wear robot suits. (Used in Gundam construction.)



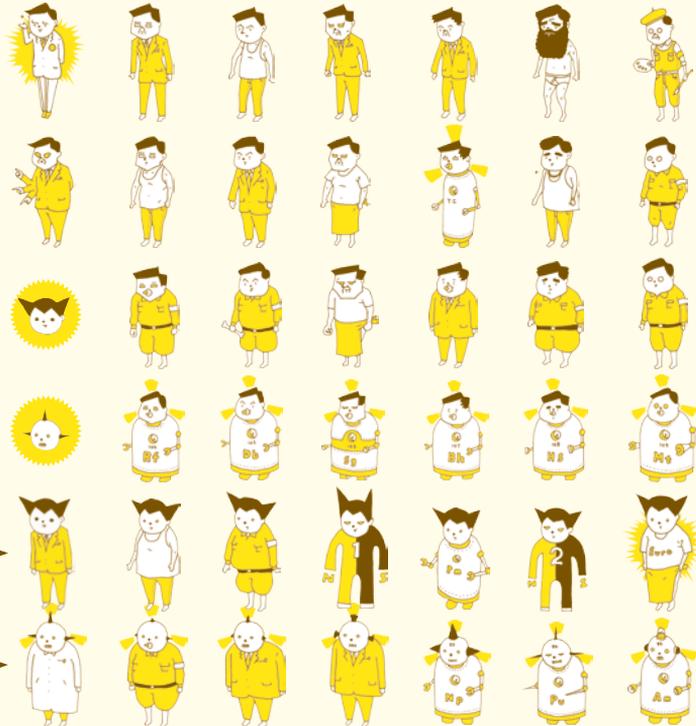


スーパー元素周期表

THE SUPER PERIODIC TABLE OF THE ELEMENTS

This is the super periodic table. You can see that the elements get heavier with each row and that the columns are grouped according to their properties. This makes it a very easy-to-understand, illustrative approach to the periodic table.

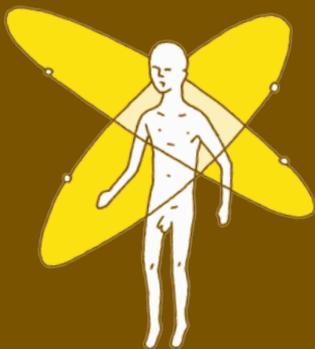
There is a poster in the back of this book with a larger version of this table, if you'd like to take a closer look.



The hard part's just beginning...



3



ELEMENT CARTOON CHARACTERS

元素キャラクター

ONE ELEMENT CAN HAVE MANY ROLES.

Now let's take a look at each element individually. What's interesting here is that each element can sometimes be found in the earth, other times in the air, and yet other times inside living beings. Oxygen, for example, erupts in a violent explosion if exposed to fire but turns into water if compounded with hydrogen. Even though we'll be looking at one element at a time, each of them has the potential to fill many different roles. I have therefore tried to limit the information in each presentation to the kind of things that you might encounter in your daily life.

BUT THERE ARE SO MANY OF THEM!

How can a normal human be expected to keep track of them all? Have no fear: If you ever feel lost, just have a look at the following index. The elements are listed in order of atomic number, so finding the one you're looking for should be a piece of cake.

Okay, enough chitchat—on to the elements!

INDEX #1

PERIOD

1 → 3

ATOMIC NUMBER

1 → 18



H

1 → 064

HYDROGEN



He

2 → 066

HELIUM



Li

3 → 067

LITHIUM



Be

4 → 068

BERYLLIUM



B

5 → 069

BORON



C

6 → 070

CARBON



N

7 → 072

NITROGEN



O

8 → 073

OXYGEN



F

9 → 074

FLUORINE



Ne

10 → 075

NEON



Na

11 → 076

SODIUM



Mg

12 → 078

MAGNESIUM



Al

13 → 079

ALUMINUM



Si

14 → 080

SILICON



P

15 → 082

PHOSPHORUS



S

16 → 083

SULFUR



Cl

17 → 084

CHLORINE



Ar

18 → 085

ARGON

INDEX # 2

PERIOD

4

ATOMIC NUMBER

19 → 36



K

19 → 088

POTASSIUM



Ca

20 → 090

CALCIUM



Sc

21 → 092

SCANDIUM



Ti

22 → 093

TITANIUM



V

23 → 094

VANADIUM



Cr

24 → 095

CHROMIUM



Mn

25 → 096

MANGANESE



Fe

26 → 098

IRON



Co

27 → 100

COBALT



Ni

28 → 101

NICKEL



Cu

29 → 102

COPPER



Zn

30 → 103

ZINC



Ga

31 → 104

GALLIUM



Ge

32 → 105

GERMANIUM



As

33 → 106

ARSENIC



Se

34 → 107

SELENIUM



Br

35 → 108

BROMINE



Kr

36 → 109

KRYPTON

INDEX # 3

PERIOD

5

ATOMIC NUMBER

37 → 54



Rb

37 → 112

RUBIDIUM



Sr

38 → 113

STRONTIUM



Y

39 → 114

YTTRIUM



Zr

40 → 115

ZIRCONIUM



Nb

41 → 116

NIOBIUM



Mo

42 → 117

MOLYBDENUM



Tc

43 → 118

TECHNETIUM



Ru

44 → 119

RUTHENIUM



Rh

45 → 120

RHODIUM



Pd

46 → 121

PALLADIUM



Ag

47 → 122

SILVER



Cd

48 → 123

CADIUM



In

49 → 124

INDIUM



Sn

50 → 125

TIN



Sb

51 → 126

ANTIMONY



Te

52 → 127

TELLURIUM



I

53 → 128

IODINE



Xe

54 → 129

XENON

INDEX # 4

PERIOD

6

ATOMIC NUMBER

55 → 86



Cs

55 → 132
CESIUM



Ba

56 → 133
BARIUM



La

57 → 134
LANTHANUM



Ce

58 → 135
CERIUM



Pr

59 → 135
PRASEODYMIUM



Nd

60 → 136
NEODYMIUM



Pm

61 → 137
PROMETHIUM



Sm

62 → 137
SAMARIUM



Eu

63 → 138
EUROPIUM



Gd

64 → 139
GADOLINIUM



Tb

65 → 139
TERBIUM



Dy

66 → 140
DYSPROSIUM



Ho

67 → 140
HOLMIUM



Er

68 → 141
ERBIUM



Tm

69 → 141
THULIUM



Yb

70 → 142
YTTERBIUM



Lu

71 → 142
LUTETIUM



Hf

72 → 143
HAFNIUM



Ta

73 → 143
TANTALUM



W

74 → 144
TUNGSTEN



Re

75 → 145
RHENIUM



Os

76 → 145
OSMIUM



Ir

77 → 146
IRIDIUM



Pt

78 → 147
PLATINUM



Au

79 → 148
GOLD



Hg

80 → 149
MERCURY



Tl

81 → 150
THALLIUM



Pb

82 → 151
LEAD



Bi

83 → 152
BISMUTH



Po

84 → 152
POLONIUM



At

85 → 153
ASTATINE



Rn

86 → 153
RADON

INDEX # 5

PERIOD

7

ATOMIC NUMBER

87 → 118



Fr

87 → 156
FRANCIUM



Ra

88 → 156
RADIUM



Ac

89 → 157
ACTINIUM



Th

90 → 157
THORIUM



Pa

91 → 157
PROTACTINIUM



U

92 → 157
URANIUM



Np

93 → 158
NEPTUNIUM



Pu

94 → 158
PLUTONIUM



Am

95 → 158
AMERICIUM



Cm

96 → 158
CURIUM



Bk

97 → 159
BERKELIUM



Cf

98 → 159
CALIFORNIUM



Es

99 → 159
EINSTEINIUM



Fm

100 → 159
FERMIUM



Md

101 → 160
MENDELEVIUM



No

102 → 160
NOBELIUM



Lr

103 → 160
LAWRENCIUM



Rf

104 → 160
RUTHERFORDIUM



Db

105 → 161
DUBNIUM



Sg

106 → 161
SEABORGIUM



Bh

107 → 161
BOHRIUM



Hs

108 → 161
HASSIUM



Mt

109 → 162
MEITNERIUM



Ds

110 → 162
DARMSTADIUM



Rg

111 → 162
ROENTGENIUM



Cn

112 → 162
COPERNICIUM



Uut

113 → 163
UNUNTRIUM



Fl

114 → 163
FLEROVIUM



Uup

115 → 163
UNUNPENTIUM



Lv

116 → 163
LIVERMORIUM



Uus

117 → 163
UNUNSEPTIUM



Uuo

118 → 163
UNUNOCTIUM

図の見方

HOW TO READ THE FIGURES

ATOMIC NUMBER

1

ELEMENT NAME

水素
Hydrogen

MOLAR MASS

Amounts of elementary entities such as atoms, molecules, and isotopes are measured in moles, where 1 mole is equal to the number of atoms in 12 grams of carbon-12 (12C). The molar masses listed here are all rounded to four significant digits, and these are the official numbers recognized by IUPAC. Also, some radioactive elements that lack stable isotopes will have the weight of an observed isotope written in square brackets instead.

1.008

1

1

氢

H

THE ELEMENT'S POSITION IN THE PERIODIC TABLE

It's at the brown dot.

CHINESE CHARACTER

The element's Chinese character

ELEMENT SYMBOL

PERIOD AND FAMILY

The number above is the element's period, and the one below is the family. Hydrogen belongs to the first period and the first family.

H

A special element that doesn't fit into any category

Multipurpose

ELEMENT CHARACTER



THE GOD ELEMENT THAT MAKES UP THE UNIVERSE

• [háidródsøn]
DISCOVERY YEAR : 1766

Hydrogen was by far the most common element in the first few minutes after the Big Bang, along with small amounts of deuterium and helium. These gases eventually formed the first stars. In a sense, hydrogen is the element that gave birth to all life. One of the most...

MELTING POINT

• -259.14 °C

BOILING POINT

• -252.87 °C

DENSITY

• 0.00008988 (GAS FORM, 0°C), g/cm³

PRONUNCIATION

DISCOVERY YEAR

MELTING POINT

The temperature at which solid matter liquifies

BOILING POINT

The temperature at which liquid matter evaporates

DENSITY

The density of an element is its mass per unit volume. Water, for example, has a density of 1. The number listed refers to the density of a solid at 20°C, unless written otherwise.

周期

PERIOD

1 → 3



原子番号

ATOMIC NUMBER

1 → 18

1



水素
Hydrogen

2



ヘリウム
Helium

3



リチウム
Lithium

4



ベリリウム
Beryllium

5



ホウ素
Boron

6



炭素
Carbon

7



窒素
Nitrogen

8



酸素
Oxygen

9



フッ素
Fluorine

10



ネオン
Neon

11



ナトリウム
Sodium

12



マグネシウム
Magnesium

13



アルミニウム
Aluminum

14



ケイ素
Silicon

15



リン
Phosphorus

16



硫黄
Sulfur

17



塩素
Chlorine

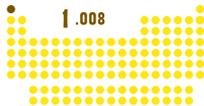
18



アルゴン
Argon

1

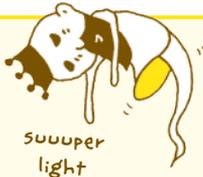
水素
Hydrogen



1

氢

H



A special element that
doesn't fit into any
category



The sun is
hydrogen
heaven!

Multipurpose



Gaseous

Heh

It's actually
really dangerous.



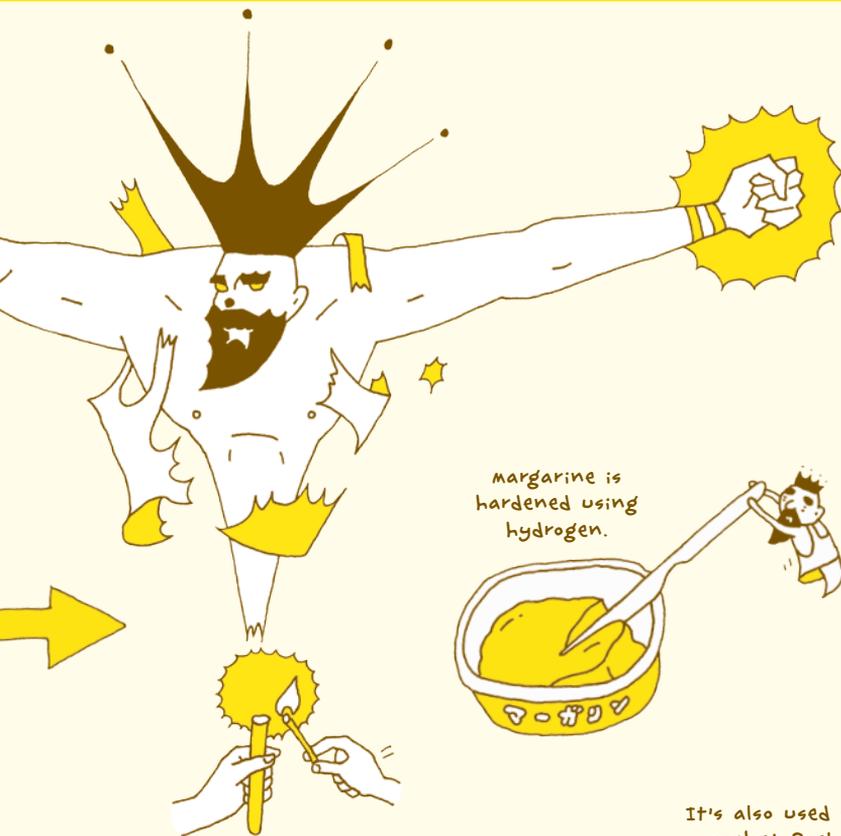
Into the
light...



**THE GOD ELEMENT
THAT MAKES UP THE
UNIVERSE**

[haidrɒdʒən]
DISCOVERY YEAR : 1766

Hydrogen was by far the most common element in the first few minutes after the Big Bang, along with small amounts of deuterium and helium. These gases eventually formed the first stars. In a sense, hydrogen is the element that gave birth to all life. One of the most basic building blocks of all life on Earth, water, is made up of oxygen and hydrogen. Our bodies are also made of over



margarine is
hardened using
hydrogen.

It's also used as
rocket fuel.

60% water, and the double helix in our DNA is strung together with hydrogen bonds. So if you're a believer, you might want to begin praying to hydrogen. One of the more recent application areas is clean energy, where it might replace fossil fuels. But even though it has helped us in so many ways, try to not get on its nerves. Hydrogen explodes if it comes in contact with fire!

MELTING POINT

-259.14

°C

BOILING POINT

-252.87

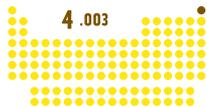
°C

DENSITY

0.00008988

(GAS FORM, 0°C)
g/cm³

2

ヘリウム
Helium

1

18

氦

He

Found in zeppelins

Noble gas

What? Whoa,
it slid out.

very fluid

Gaseous

It becomes a
wall-climbing
liquid at -271°C .

sound waves

Raises the
pitch of
your voice

**THE LIGHTEARTED GAS
THAT RAISES OUR SPIRITS
AND OUR VOICES**

[hēliəm]

DISCOVERY YEAR : 1868

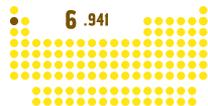
Children know it from funny voices and balloons. This ancient element could be found along with hydrogen minutes after the Big Bang. And without these two, no other elements could have been formed. They are the only two elements that are lighter than air, so maybe they're kind of like the leaders, looking down on all the others? But helium, unlike hydrogen, is one cool cookie and doesn't explode easily at all.

MELTING POINT
-272.2
(PRESSURIZED) °C

BOILING POINT
-268.934
°C

DENSITY
0.0001785
(GAS FORM, 0°C),
g/cm³

3

リチウム
Lithium

鋰

Li



THE POWER SOURCE OF THE MOBILE AGE

[liθiam]
DISCOVERY YEAR : 1817

Lithium, the lightest metal, was also born at the time of the Big Bang, so hydrogen, helium, and lithium are actually triplets. But there was so little lithium at the time, it couldn't do much. Today, however, it is an essential component in both lithium ion batteries and mobile devices. It's light, powerful, and easy to recharge, and it doesn't really deteriorate. It can also be found in seawater, so we won't run out anytime soon.

MELTING POINT
180.54

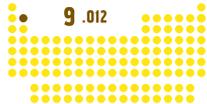
°C

BOILING POINT
1340

°C

DENSITY
0.534
(0°C)
g/cm³

4

ベリリウム
Beryllium2
—
2

铍

Be



**SUPER TALENTED!
ELITE AND LEGENDARY!**

[berilium]

DISCOVERY YEAR: 1797

It's the elite metal with skills galore: It weighs two-thirds what aluminum does, it resists heat with a melting point of 1278°C, and it can create springs that can withstand over 20 billion contractions. Yet it still leads a tragic life due to the fact that its particles form a deadly poison. Since it's hard to forge anything without first powdering the materials, it has not been adopted in mass production.

MELTING POINT
1278 ± 5

°C

BOILING POINT
2970
(PRESSURIZED)

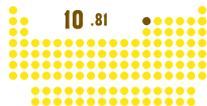
°C

DENSITY
1.847

g/cm³

5

ホウ素
Boron



2

13

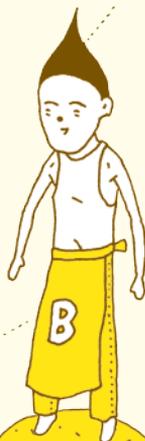
硼

B

Heat-resistant glass



The boron family



Stab

Dehydrates cockroaches using poisonous bait



Fake snow in movies



Disinfecting properties



HELPING OUR DAILY LIVES
IN SO MANY WAYS

[bò:ran]

DISCOVERY YEAR: 1892

We mostly use boron in compounds. For example, the technical term for the heat-resistant glass Pyrex is *borosilicate glass*, created by adding boron oxide to keep the glass from swelling and shrinking. Harder diamonds can be created by combining boron with carbon. Finding new boron combinations is a great way for a chemist to show off; two Nobel prizes have been awarded for boron compound research.

MELTING POINT
2300

°C

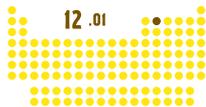
BOILING POINT
3658

°C

DENSITY
2.34
(TYPE B)
g/cm³

6

炭素 Carbon



2

14

碳

C

A friend from ancient times



charcoal

In calligraphy ink



炭

The carbon family



Multipurpose

Appears in many different forms

Solid

Water purification



Activated charcoal



Air purification

PART OF EVERY LIVING THING

[Ká:rbən]
DISCOVERY YEAR: ANCIENT

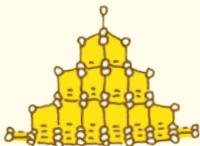
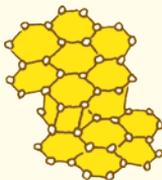
Carbon is the building block of all life. One could argue that the food chain should instead be called something like “the carbon tug-of-war.” Carbohydrates, proteins, and all the other nutrients that we require are made up of carbon compounds. The same is also true of our cells, DNA, and the plants we eat. (Plants create their carbohydrates from carbon dioxide through a process called



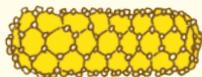
Its properties
change
depending on
how it binds
together.



pencil
graphite



Diamonds



carbon
nanotubes



All living
things

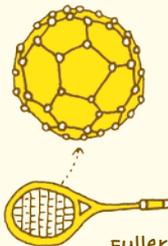
There are over 10,000,000
different naturally occurring
carbon compounds.

photosynthesis.) The fourth most abundant element in the universe, carbon comes in many forms, from the graphite in our pencils to diamonds. The forms are so different that it's hard to believe that they're made from the same element. It appears today in oil, plastics, clothes, and medicines. It has also drawn a lot of recent attention with the advent of carbon nanotube research.

MELTING POINT
3550
(DIAMOND) °C

BOILING POINT
4827
(SUBLIMATION) °C

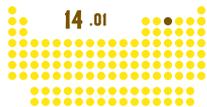
DENSITY
3.513
(DIAMOND)
g/cm³



Fullerene,
used in tennis
rackets and
golfclubs

7

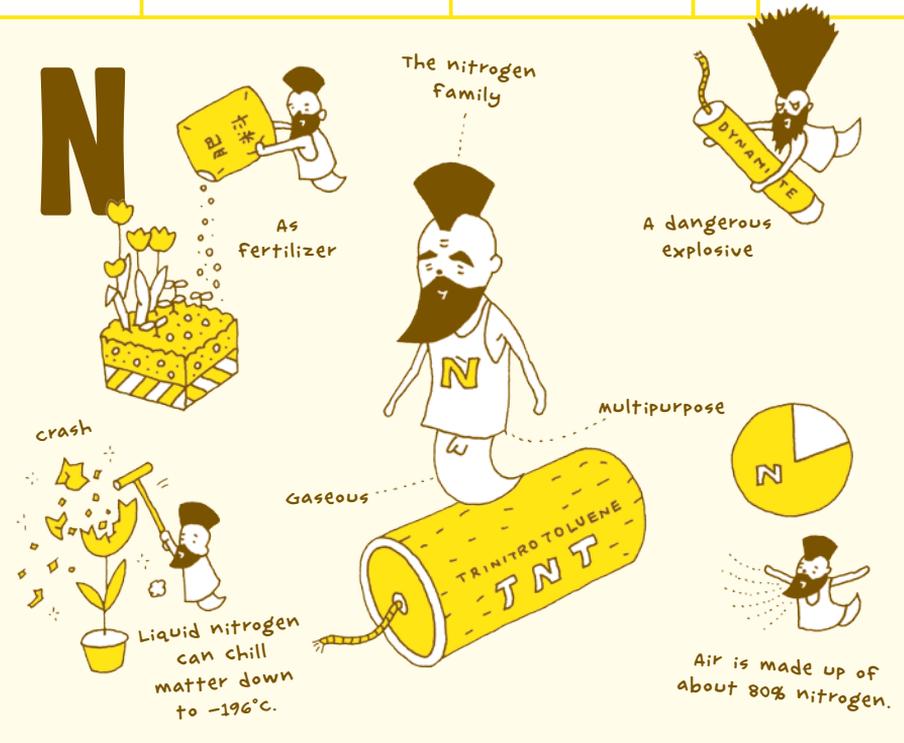
窒素
Nitrogen



2

氮

15



**LOOKS FRIENDLY AND COOL,
BUT CAN BE DANGEROUS**

[náitredʒən]

DISCOVERY YEAR: 1772

Making up about 80% of the air we breathe, nitrogen is also the main component of our DNA and the amino acids that make up the proteins in our bodies. It may seem docile, but most explosives—like nitroglycerin and dynamite—are made using nitrogen compounds. Combined with oxygen, it's also a major pollutant. Liquid nitrogen is used in such diverse applications as cryogenics and the preparation of ultra-smooth ice cream.

MELTING POINT
-209.86

°C

BOILING POINT
-195.8

°C

DENSITY
0.0012506
(GAS FORM, 0°C),
g/cm³

8

酸素
Oxygen



2

16

氧

0

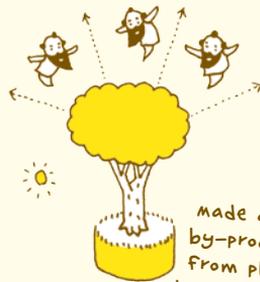


The ozone layer that absorbs harmful ultraviolet radiation



$O_3 = \text{ozone}$

The oxygen family



Made as a by-product from plant photosynthesis



Gaseous

Multipurpose



When something burns, it's actually binding with oxygen.



THE SINGLE-MINDED ELEMENT THAT PROTECTS EARTH

[aksidʒən]

DISCOVERY YEAR: 1774

The oxygen most living things need to breathe makes up about 20% of our air and is created primarily through plant photosynthesis. Fire also uses up oxygen when it burns, and the ozone layer that protects us from the sun's ultraviolet rays is made out of it. Rust and rot are also just two types of *oxidation*, which occurs when oxygen binds with different elements and changes their properties.

MELTING POINT

-218.4

°C

BOILING POINT

-182.96

°C

DENSITY

0.001429

(GAS FORM, 0°C)
g/cm³

9

フッ素
Fluorine

19.00

2
17

フッ素

Food won't burn and stick!

F



Halogen

Teflon
frying pans

Daily uses

super
shiny

Gaseous



THE TIDY POISON

[fluəri:n]

DISCOVERY YEAR: 1886

When we think of fluorine, we might think of toothpaste or frying pans. It sticks to our teeth after we've brushed them, helping to protect them from bacteria. And coating frying pans and umbrellas with fluorine resin makes it hard for things to stick to them. Pure fluorine, however, is very poisonous, and isolating it from its compounds was no simple feat. The first to do this, the French chemist Moissan, received a Nobel prize.

MELTING POINT

-219.62

°C

BOILING POINT

-188.14

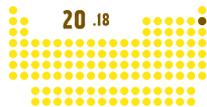
°C

DENSITY

0.001696

(GAS FORM, 0°C),
g/cm³

10

ネオン
Neon

2

18

氖

Ne



shines red
when subjected
to electrical
discharge



specialist
uses



The first neon
sign was made
in montmartre,
Paris in 1912.



**THE BEACON OF THE NIGHT
WAS BORN IN PARIS**

[nī:an]

DISCOVERY YEAR: 1898

The neon lights that color our cities at night all work by discharging electricity into neon gas encapsulated in glass tubes. The first time this was done was in 1912 in Montmartre, Paris. Neon, normally a very stable gas, shines reddish orange when subjected to electricity. This color can be changed, though, by adding other elements. Helium makes it yellow, mercury makes it turquoise, and argon makes it blue, for example.

MELTING POINT

-248.67

°C

BOILING POINT

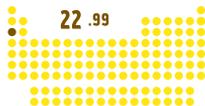
-246.05

°C

DENSITY

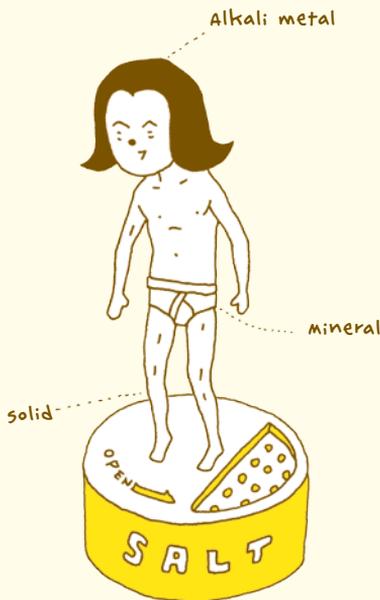
0.00089994
(GAS FORM, 0°C)
g/cm³

11

ナトリウム
Sodium3
—
1

钠

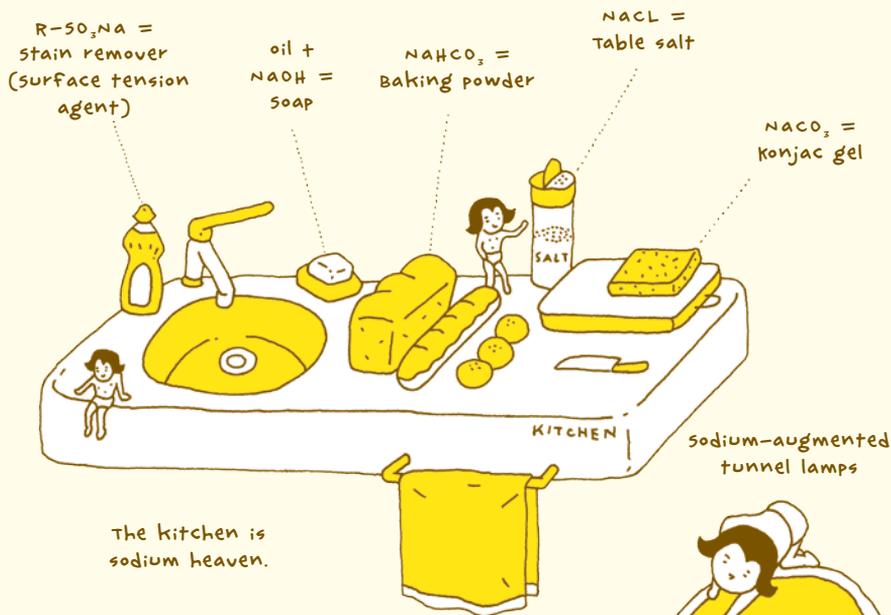
Na



**MOTHER'S FAVORITE,
GOOD FOR BOTH FOOD AND
CLEANING!**

[sôdiâm]
DISCOVERY YEAR: 1807

Sodium compounds are great for housework! For example, table salt (sodium chloride) and baking powder (sodium bicarbonate) are both essential for cooking. Cleaning supplies such as bleaching agents and soaps are based on sodium compounds. Bathing powders and bubble baths are mostly made out of sodium-hydrogen



carbonates. But this loved and popular character also has some dangerous properties. Many sodium compounds are highly water soluble, but if pure sodium comes in contact with water, it explodes, proving it to be something of a gremlin element! That's why it's popular to store it in oil or some other non-water liquid.

MELTING POINT

97.81

°C

BOILING POINT

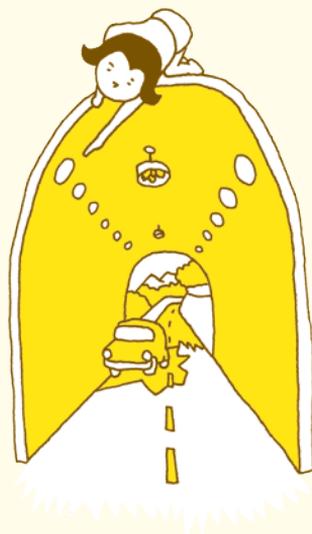
883

°C

DENSITY

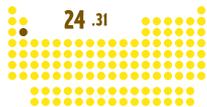
0.971

g/cm³



12

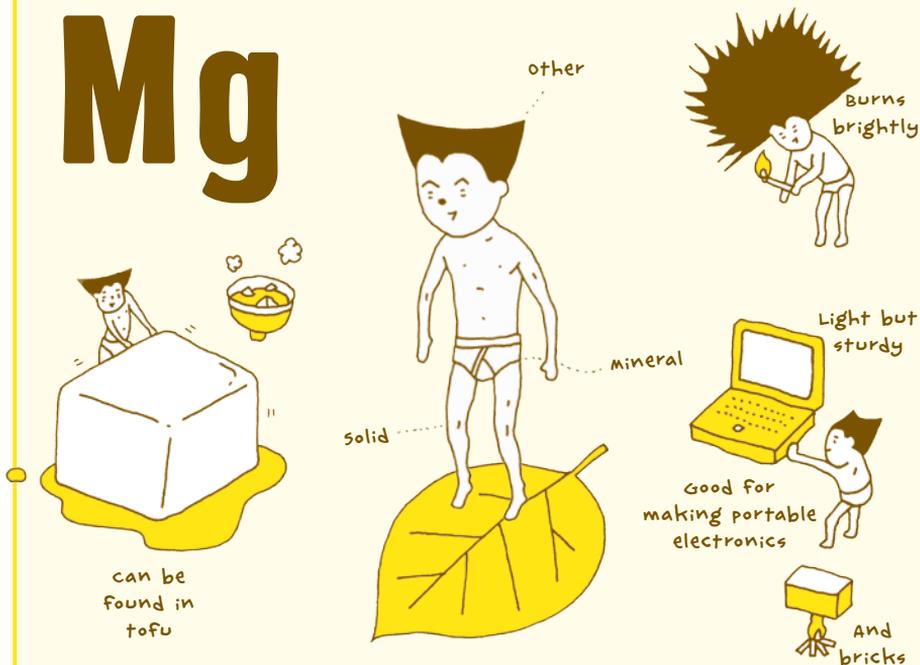
マグネシウム
Magnesium



3
—
2

鎂

Mg



**THE SUPER SKILLED
HONOR STUDENT?!**

[mægni:ziəm]

DISCOVERY YEAR: 1808

Lighter than aluminum and as strong as steel, magnesium has good electrical and magnetic insulation properties and does not retain heat. That's why it's perfect for laptop and cell phone shells. But magnesium is not just a techie element, as it's found in abundance both in tofu and in the chlorophyll that makes plants green. On top of all these other talents, it's also good for clearing constipation!

MELTING POINT
650

°C

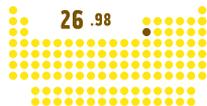
BOILING POINT
1095

°C

DENSITY
1.738

g/cm³

13

アルミニウム
Aluminum

3

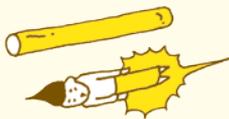
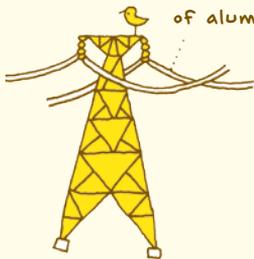
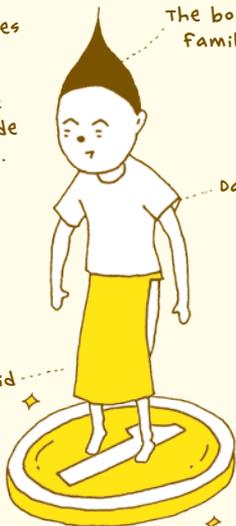
13

铝

Al



sapphires

High-voltage
wires are made
of aluminum.very
conductiveThe boron
family

Daily uses

solid

used in one-yen coins



Light

duralumin
cases are
made of
aluminum
alloys.window
framescan be found in all
kinds of everyday
thingsstreet
signsAluminum
cansTHE MOST COMMON METAL
ON EARTH[ə'lʊ:mɪnəm]
DISCOVERY YEAR: 1807

Aluminum is a light metal that's very easy to work with. It doesn't rust, conducts electricity well, and is extremely cheap. It can also be alloyed easily to add properties of other metals, producing things like coins, aluminum foil, window frames, and airplane body parts. It has protective properties when applied to stomach membranes and works great as a stress reliever—a good thing in our stress-filled society.

MELTING POINT

660.37

°C

BOILING POINT

2520

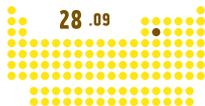
°C

DENSITY

2.698

g/cm³

14

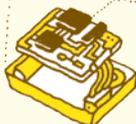
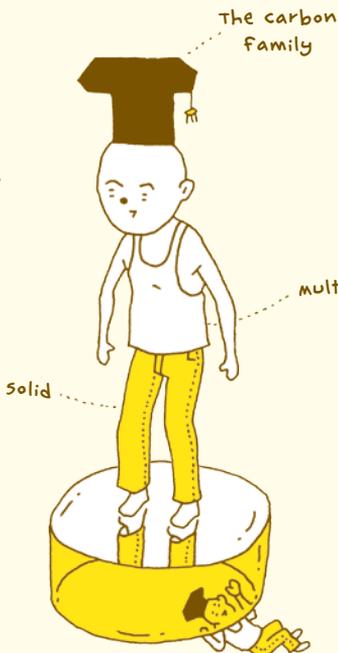
ケイ素
Silicon

3

14

矽

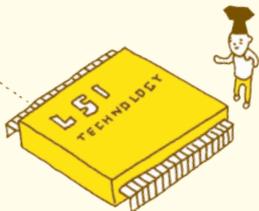
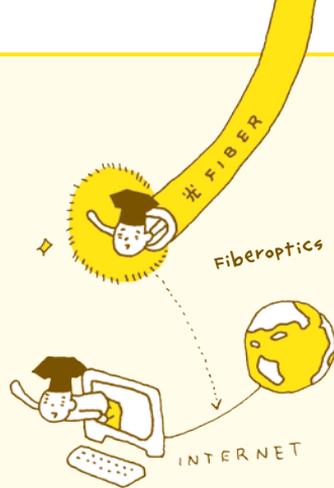
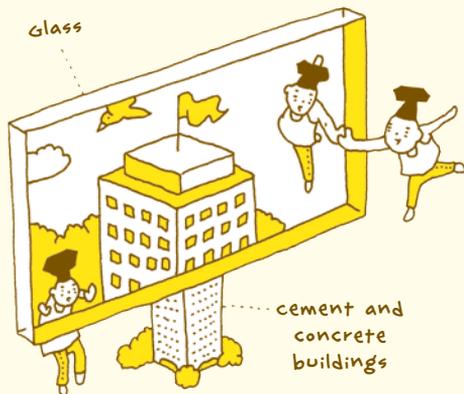
Si

It's sand,
basically.All
manner of
containersLSI
The basic
material used
to make
integrated
circuits.Multipurpose
For
semiconductorsHee hee
silicone
is silicon
plastic.THE DIGITAL ARTISAN
FROM THE DESERT

[silikon]

DISCOVERY YEAR: 1823

The next time someone asks you about silicon, just point at some sand. It is the second most abundant element on Earth and can be found as silicon dioxide or silicate in (for example) quartz and crystals. In olden times, it was often used for making glass due to its strength, but it's now the mainstay of the digital age. We treasure it as vital to creating semiconductors and solar batteries. Silicone



rubber is used to make baby bottle caps and breast implants, among other things. Silicon dioxide-rich sand has heat-resistant properties and is used to make bricks and building walls. The insulation material asbestos was popular at the end of the 19th century, but now we know that asbestos fibers can accumulate in the lungs and are highly carcinogenic. Pure silicon isn't poisonous at all, though.

MELTING POINT

1410

°C

BOILING POINT

2355

°C

DENSITY

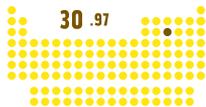
2.329

g/cm³



conditioner

15

リン
Phosphorus

3

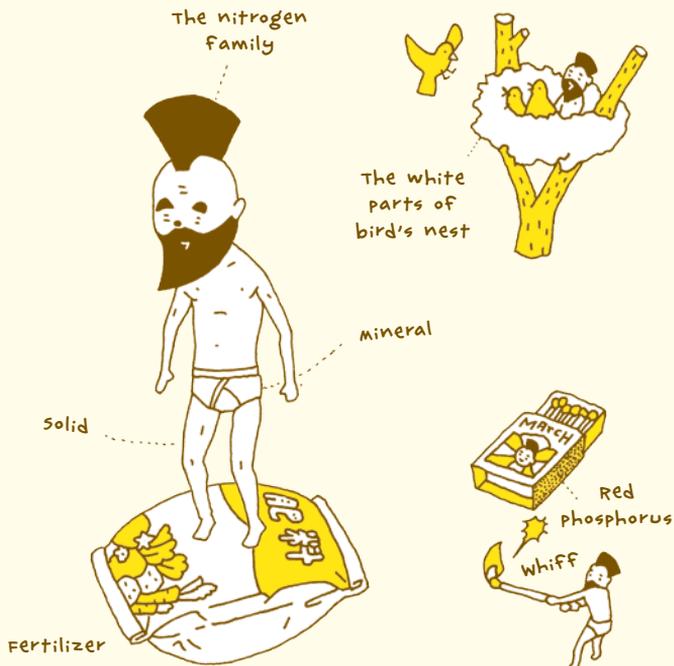
15

石_二磷_一

P

The three
essential
plant
elements

N . K . P



Fertilizer

IT ALL STARTED WITH PEE!
THE LIVELY ELEMENT

[fásferos]

DISCOVERY YEAR: 1669

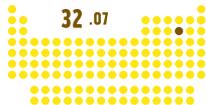
About when Isaac Newton was busy dodging falling apples, German alchemists were evaporating urine in their experiments, which led to the discovery of phosphorus. It can be found in several colors, among them white, red, and purple. Our DNA and cells crave it to function properly. It is also essential in agriculture as fertilizer. Red phosphorus is used in the striking surfaces of matches and flares and in cap gun caps.

MELTING POINT
44.2
(WHITE PHOSPHORUS)
°C

BOILING POINT
279.9
(WHITE PHOSPHORUS)
°C

DENSITY
1.82
(WHITE PHOSPHORUS)
g/cm³

16

硫黄
Sulfur

3

16

硫

S

The oxygen family

For the skin

Effective as medicine



can be found in the keratin in our hair



Antibiotics (penicillin)



makes onions and garlic spicy

solid

Multipurpose



Stinky!

Rubber sulfur



Tires

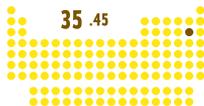
THE STINKY
VITALITY SOURCE![sʌlfə]r
DISCOVERY YEAR: ANCIENT

The rotten egg stink of hot springs and the strong smell of garlic and onions are all due to sulfur. But good medicine tastes bitter! The amino acids in our bodies contain sulfur, and sulfur has helped us for decades as part of the world's first antibiotic. Sulfur dioxide, a by-product of combustion engines, is a major pollutant as it can eventually form sulfuric acid in the atmosphere and fall as acid rain.

MELTING POINT
112.8
(CRYSTALLINE FORM) °CBOILING POINT
444.674
°CDENSITY
2.07
(CRYSTALLINE FORM)
g/cm³

17

塩素
Chlorine



3

17

氯

Cl



As a swimming
pool antibacterial
agent



Table salt is
a chlorine
compound.

sodium
chloride



Halogen

Multipurpose

Gaseous



chlorine
gas is very
poisonous.



Bleaches

KILLS BACTERIA!
THE UNRIVALED CLEAN-FREAK

[klo:ri:n]

DISCOVERY YEAR: 1774

Chlorine is commonly used in water purification plants and pool water as an antibacterial agent. But while it has more or less eradicated epidemic water diseases such as typhoid and cholera, it was also used as a chemical weapon during World War I. It is also used in many everyday items, such as PVC plastics, water pipes, and erasers. Though chlorine itself is very poisonous, chloride ions are necessary to most forms of life.

MELTING POINT

-100.98

°C

BOILING POINT

-33.97

°C

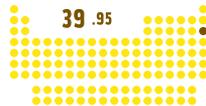
DENSITY

0.003214

(0°C)

g/cm³

18

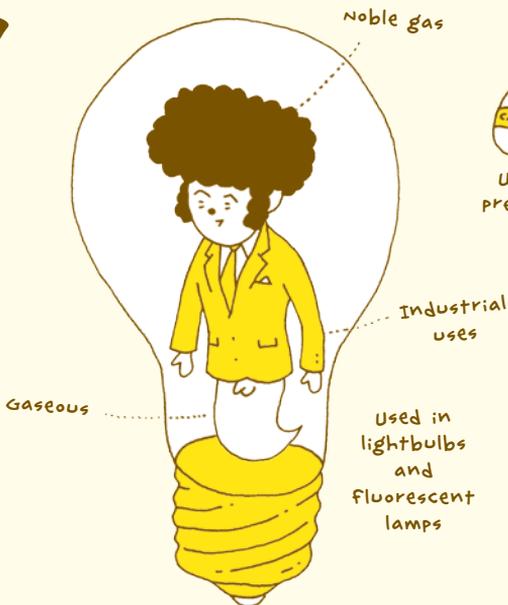
アルゴン
Argon3
18

氩

Ar



The third most
common gas in
the atmosphere



Industrial
uses

Used in
lightbulbs
and
fluorescent
lamps



AFFABLE AND EASYGOING

[á:rgən]
DISCOVERY YEAR: 1894

Argon gas doesn't react with anything under normal circumstances, which makes it ideal as a preservative for old texts and to isolate experimental materials that react violently with oxygen and hydrogen. It can also be found in fluorescent lights, where it makes it easier for the cathodes in the lamp to discharge electricity. Earth's atmosphere is made up of 78% nitrogen, 21% oxygen, and 1% argon.

MELTING POINT
-189.37 °C

BOILING POINT
-185.86 °C

DENSITY
0.001784
(GAS FORM, 0°C)
g/cm³

周期

PERIOD

4



原子番号

ATOMIC NUMBER

19 → 36

19



カリウム
Potassium

20



カルシウム
Calcium

21



スカンジウム
Scandium

22



チタン
Titanium

23



バナジウム
Vanadium

24



クロム
Chromium

25



マンガン
Manganese

26



鉄
Iron

27



コバルト
Cobalt

28



ニッケル
Nickel

29



銅
Copper

30



亜鉛
Zinc

31



ガリウム
Gallium

32



ゲルマニウム
Germanium

33



ヒ素
Arsenic

34



セレン
Selenium

35



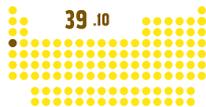
臭素
Bromine

36



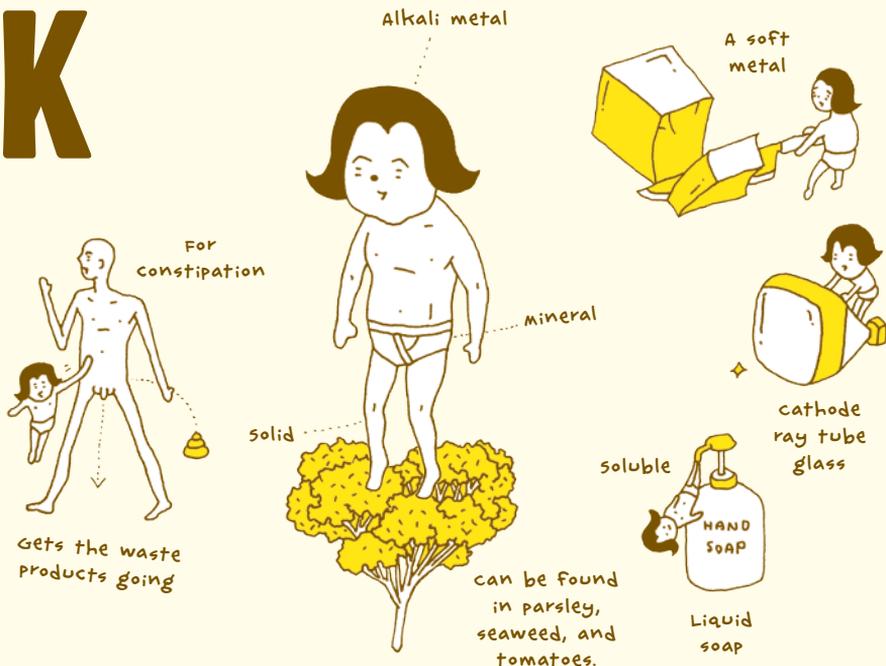
クリプトン
Krypton

19

カリウム
Potassium4
—
1

鉀

K

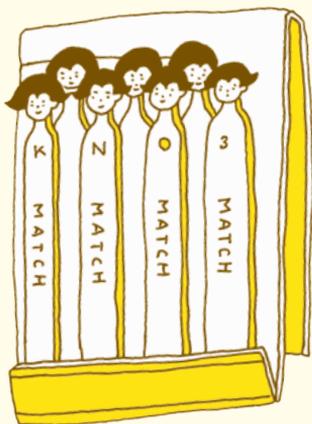


THE ULTRA-LIVELY MINERAL ELEMENT

[potæsiəm]
DISCOVERY YEAR: 1807

Potassium is a mineral that is vital to our bodies and is also one of three main fertilizers used in agriculture. Both potassium and sodium use our cells as their workplace, where they fire nerves and contract muscles. Potassium can also form a multitude of salts with varying properties, depending on which element it bonds with. In addition to the sulfuric and chlorine salts used in fertilizers,

Potassium nitrate in match heads



Laundry detergent can be created by dissolving plant potassium in water.



Finely divided potassium can spontaneously combust in air, so it's usually preserved in oil.

potassium fatty acid salts are used in the production of soaps. Potassium nitrate (an ionic salt) is used in fireworks and gunpowder. But even though it's found in many places around the house, potassium is the basis for some very famous poisons. In fact, the poison that we call cyanide is actually a highly soluble compound composed of potassium, carbon, and nitrogen.

MELTING POINT

63.65

°C

BOILING POINT

774

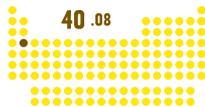
°C

DENSITY

0.862
(-80°C)

g/cm³

20

カルシウム
Calcium4
—
2

鈣

Ca

Alkaline
earth metalBurns with
an orange
tintcan be found in
milk and yogurt

solid

Mineral

chalk is
calcium.**BONES AND SHINING TEETH,
THE WHITE-CLAD WORKER**

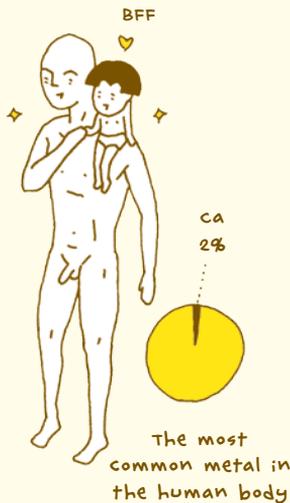
[kãłsiəm]

DISCOVERY YEAR: 1808

Pure calcium is a white metal. It's a well-known ingredient in both yogurt and milk, and it's one of the most sold elements in existence. A grown human body contains approximately 1 kg of calcium, which makes up our skeleton and teeth, among other things. Recent advances in science have enabled us to artificially create the main component of bone, calcium phosphate. This has in turn given us the



marble is also calcium
(calcium carbonate).



Wall plaster is
calcium, too!



Limestone
caves



Antifreezing
agents used on
roads in winter

technology to manufacture more natural tooth prostheses for people who don't like amalgam fillings. Does it feel kind of strange, knowing that almost all of the minerals in our bodies are actually different kinds of metal? One fun fact is that the nutrients known as vitamins often get discussed together with minerals even though they're not really basic elements. Vitamins are actually organic compounds!

MELTING POINT

839

°C

BOILING POINT

1484

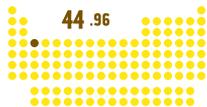
°C

DENSITY

1.55

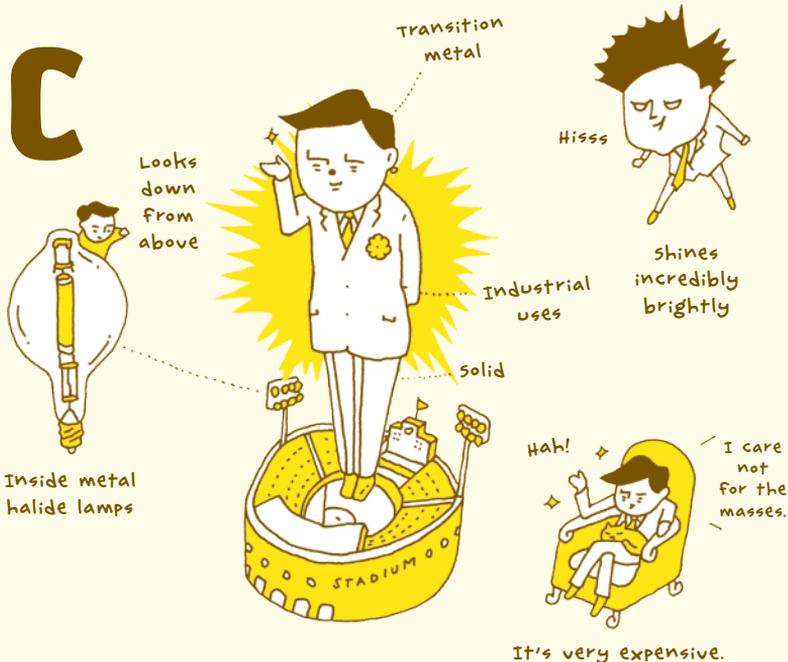
g/cm³

21

スカンジウム
Scandium4
—
3

钪

Sc



PRICY BUT BLAND, THE SMALL-TIME CELEBRITY

[skændiəm]
DISCOVERY YEAR: 1879

Compared to other elements with a low atomic number, scandium is rare and very expensive. While its weight and other properties are similar to those of aluminum, its melting point is twice as high. A scandium fluorescent tube shines twice as brightly, consumes less electricity, and lasts longer than its halogen counterpart. It's easy to see why these lights are used in high-end cars and stadiums.

MELTING POINT

1541

°C

BOILING POINT

2831

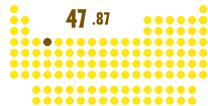
°C

DENSITY

2.989

g/cm³

22

チタン
Titanium4
—
4

钛

Ti

Dictionary
pagesGlasses
frames

solid



GOLF HEAD

Transition
metalIndustrial
usesDissolves dirt and
cleans off water
dropsTitanium
oxide
coatingstrong against
decayTHE SUPER-USEFUL
SMART METAL[tài-tí-ni-um]
DISCOVERY YEAR: 1795

Used for glasses, piercings, golf clubs, cosmetics, and many other everyday items, titanium was used only for fighter aircraft and submarines until about 30 years ago, when new mining technology brought this metal to the people. It's very nonreactive, able to resist corrosion from both seawater and chemical compounds, and popular among people with metal allergies. It is also light, strong, and abundant.

MELTING POINT

1760

°C

BOILING POINT

3287

°C

DENSITY

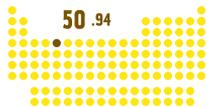
4.54

g/cm³

23

バナジウム

Vanadium



4

5

钒

V



Rumored
to be
good
for the
health

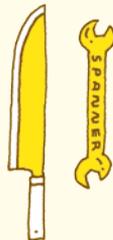


solid



Transition
metal

Multipurpose



Vanadium steel
is very hard.



Blue paint
(vanadium zirconium blue)

THE CONTROVERSIAL OCEANIC MINERAL

[vanéidiəm]
DISCOVERY YEAR: 1830

Some scientists believe that vanadium can have positive effects on your blood sugar levels. Whether this is true or not, the groundwater around Mount Fuji contains lots of it and is therefore sometimes called "Vanadium water." Some types of seaweed and moss are also rich in the mineral, as well as some types of marine invertebrate filter feeders like sea squirts, which have vanadium in their bloodstream.

MELTING POINT

1887

°C

BOILING POINT

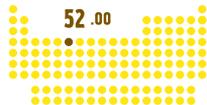
3377

°C

DENSITY

6.11
(19°C)g/cm³

24

クロム
Chromium4
—
6

铬

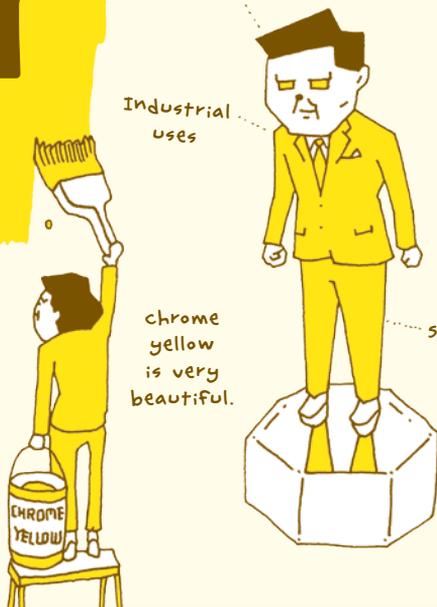
Cr

Transition
metalIndustrial
useschrome
yellow
is very
beautiful.

Solid

chrome
platingDoesn't
rust

STAINLESS

Stainless steel
Fe - Ni - CrBrings out
the color in
emeralds and
rubiesHexavalent
chromium is
very toxic.

THE TORTURED ARTIST

[króumiam]
DISCOVERY YEAR: 1797

Many have lost trust in chromium because of pollution issues. But these stem mainly from the hexavalent chromium oxidation state, while the trivalent state is an essential trace mineral. Chromium is also the basis for many beloved hues, such as viridian and the vivid colors of emeralds and rubies. And it is one of the components of stainless steel. One hopes that its accomplishments have garnered it a little honor.

MELTING POINT

1857

°C

BOILING POINT

2672

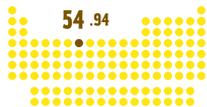
°C

DENSITY

7.19

g/cm³

25

マンガン
Manganese4
7

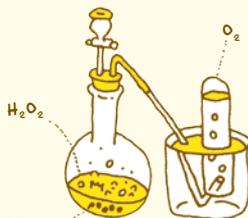
錳

Mn

Transition
metal
 $Fe + Mn = \text{a very strong compound}$
Industrial
uses

The cables on the
great seto bridge
are made of
manganese steel.

solid

Manganese
dioxide

often used
in scientific
experiments

**A WORKER OF OLD,
THE UNSUNG HERO OF THE
ELEMENTS**

[mæŋgəni:s]

DISCOVERY YEAR: 1774

Famous as the raw material for dry cell batteries, manganese is a metal found both on dry land and on the sea floor. But while manganese batteries have been in use since the late 19th century, they are gradually being replaced by the alkali family of batteries (though actually there isn't much difference between the materials used in these two battery types). Manganese is also necessary for our metabolism.

MELTING POINT

1244

°C

BOILING POINT

1962

°C

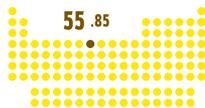
DENSITY

7.44

g/cm³



26

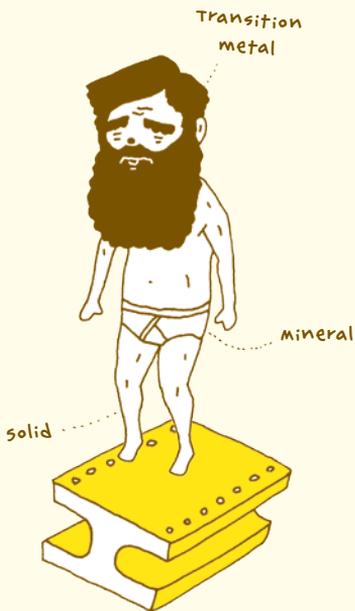
鉄
Iron4
—
8

鉄

Fe

Body
warmers

Tapes



Trains



Ships

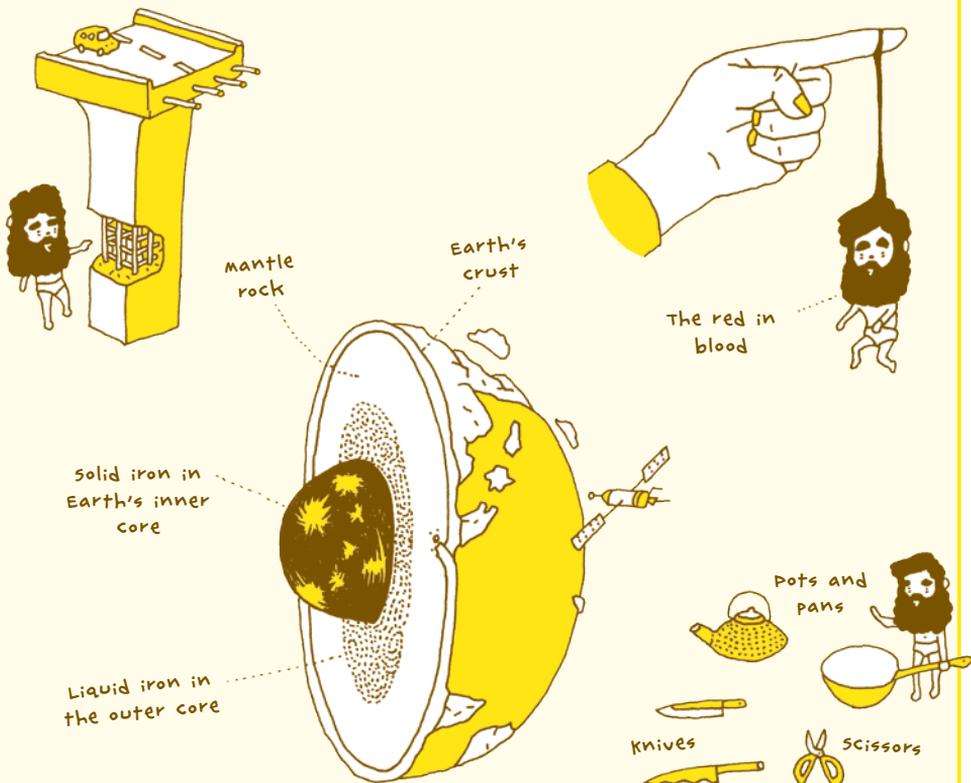


Cars

THE COGWHEEL OF DESTINY THAT SET CIVILIZATION IN MOTION

[áiərn]
DISCOVERY YEAR: ANCIENT

The discovery of iron was the turning point for all humankind, allowing us to throw away our stone tools and set out on the path to civilization. The first people to use iron were the ancient Hittites in 1500 BCE. After their kingdom fell, the Hittite people spread across the globe, taking their craft with them and bringing a gradual but significant change to people's lives. Iron still accounts for



roughly 90% of the world's total metal production, and since it is incredibly abundant, easy to work with, strong, and cheap, it will probably continue to be a recipe for success far into the future. We are even more fundamentally dependent on iron, though, as the hemoglobin that carries oxygen in our blood also contains iron. It's all around us, as well as inside us.

MELTING POINT

1535

°C

BOILING POINT

2750

°C

DENSITY

7.874

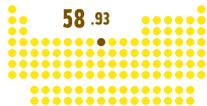
g/cm³



Weapons

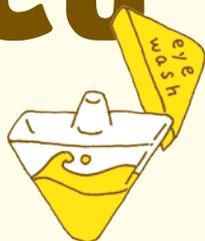
There are just so many things made of iron.

27

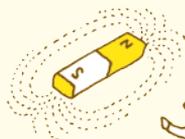
コバルト
Cobalt4
9

钴

Co



Eye drops



magnets



Industrial uses

No art
without
cobalt

THE BLUE-CLAD DIGITAL TECHNICIAN

[kóubó:it]
DISCOVERY YEAR: 1737

You probably know cobalt from its charming signature color, cobalt blue, but did you know that its name comes from the German word *kobold*, which means goblin? Silver miners in 18th century Germany simply didn't know how to react when they encountered veins of this ghastly blue metal that gave off toxic fumes. Nowadays its magnetic and sensitive properties make it ideal for use in computer hard disks and many other items.

MELTING POINT

1495

°C

BOILING POINT

2870

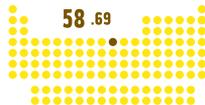
°C

DENSITY

8.9

g/cm³

28

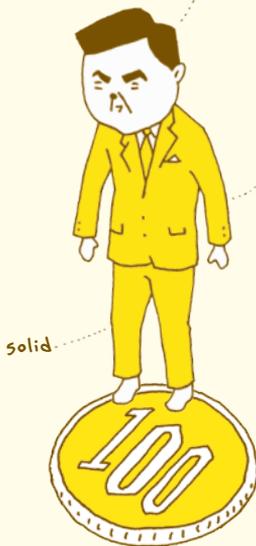
ニッケル
Nickel

4

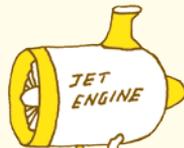
10

鎳

Ni

underwire
bras

solid

Transition
metalIndustrial
usescharging nickel-
metal hydride
batteries with
solar panelsIn
enginesHeat
resistant

THE MONEY MAKER

[nikel]
DISCOVERY YEAR: 1751

The copper-nickel alloy *cupronickel* is used in American nickels and in Japanese 100-yen and 50-yen coins. Over 1,000,000 tons of nickel are produced worldwide every year. The metal is used in a multitude of alloys, especially iron alloys like stainless steel but also shape-memory titanium alloys. Nickel has gotten a lot of attention lately with the advent of environmentally friendly nickel-metal hydride rechargeable cell batteries.

MELTING POINT

1455

°C

BOILING POINT

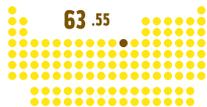
2890

°C

DENSITY

8.902
(25°C)g/cm³

29

銅
Copper

4

II

銅

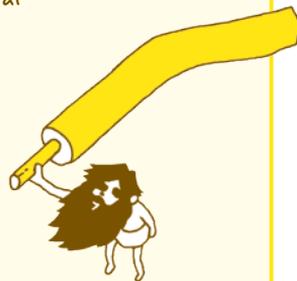
Cu

Copper
statuesTransition
metalSpider, snail,
and octopus
blood

mineral



solid

10-yen coins are
made of bronze.copper wires are
very conductive.THE METAL WE'VE CARED FOR
THE LONGEST

[káper]

DISCOVERY YEAR: ANCIENT

The oldest known man-made metal object is a 10,000-year-old copper pendant found in Iraq. Copper conducts heat well and is easy to work with. It's too brittle to use for anything other than household tools, but alloying copper with tin to produce bronze made it possible to construct weapons, musical instruments, farming tools, and more—an event so important, we call it the Bronze Age. Copper deserves a gold medal!

MELTING POINT

1083.5

°C

BOILING POINT

2567

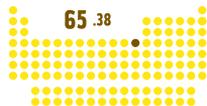
°C

DENSITY

8.96

g/cm³

30

亜鉛
Zinc

4

12

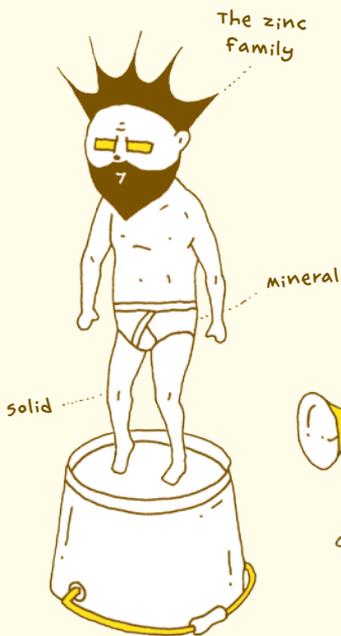
鋅

Zn

Fe + Zn plating



Galvanized sheet metal is great for water buckets and roofs.



oysters contain a lot of zinc.



copper + zinc = brass

THE PICKY GOURMET ELEMENT

[zɪŋk]
DISCOVERY YEAR: MEDIEVAL

Zinc is a very important trace mineral, second in our bodies only to iron. For example, it helps the tongue cells in our taste buds process our sense of taste. This is why zinc deficiencies often lead to an impaired appetite. It's also an excellent construction material, creating alloys such as galvanized sheet metal with iron and brass with copper. It has also recently been used as raw material in creating blue LEDs.

MELTING POINT

419.58

°C

BOILING POINT

907

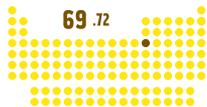
°C

DENSITY

7.133

g/cm³

31

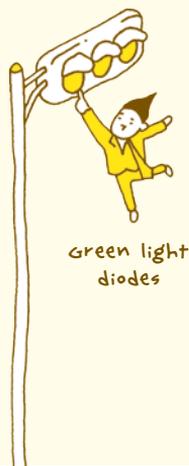
ガリウム
Gallium

4

13

鎳

Ga



THE KIND, NERDY ELEMENT

[gæliəm]
DISCOVERY YEAR: 1875

Are you wondering, “WTF is gallium?” Well, you should be ashamed! In addition to being a vital part of both game consoles and Blu-ray players, it’s also used in semiconductors and LEDs. Gallium nitride is in almost all new video equipment, driving the powerful blue lasers that were unattainable with lesser technology. This has allowed us to achieve higher resolutions, sharper colors, and a more awesome entertainment experience.

MELTING POINT

29.78

°C

BOILING POINT

2403

°C

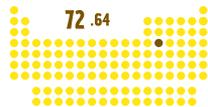
DENSITY

5.907

g/cm³

32

ゲルマニウム
Germanium



4

14

锗

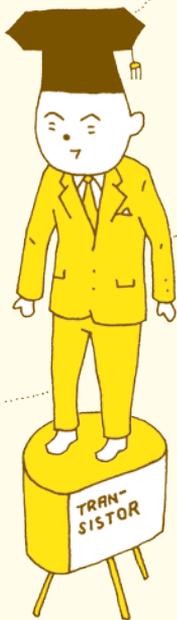
Ge

Nostalgia...



The first
germanium radio

The carbon family



solid

Industrial
uses



In wide-angle
camera lenses



Not very popular
nowadays

THE ELEMENT FROM THE GOOD OLD DAYS

[dʒərméiniəm]
DISCOVERY YEAR: 1885

This element might be familiar to the audio-philosophers out there, since the heart of the world's first transistor radio (produced by Sony in 1953) was made of germanium. It was used widely at the dawn of the semiconductor age but has since been replaced by other elements. Recent rumors hint that it might be good for the health, though, with its name appearing on several products such as "germanium hot baths."

MELTING POINT

937.4

°C

BOILING POINT

2830

°C

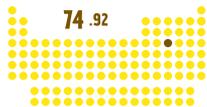
DENSITY

5.323

g/cm³

33

ヒ素
Arsenic



74.92

4

15

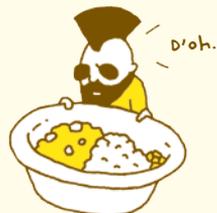
砷

As

Used in semiconductors
with gallium and indium



can be found in
some types of
edible seaweed



Used as a poison
too many times



It can also be used to
make medicine.

THE RUTHLESS DARK-SIDE ELEMENT

[ɑ:rsənik]
DISCOVERY YEAR: MEDIEVAL

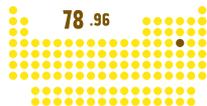
Most people probably know arsenic as a poison, rumored to be responsible for the deaths of Napoleon Bonaparte and King George III. It blocks enzymes when introduced to the bloodstream, and it is both odorless and tasteless, which makes it very hard to detect when hidden in food. Some types of seaweed naturally contain arsenic, but not enough to make you sick. Arsenic is widely used for making semiconductors.

MELTING POINT
817
(METAL,
PRESSURIZED) °C

BOILING POINT
616
(SUBLIMATION) °C

DENSITY
5.78
(METAL)
g/cm³

34

セレン
Selenium

4

16

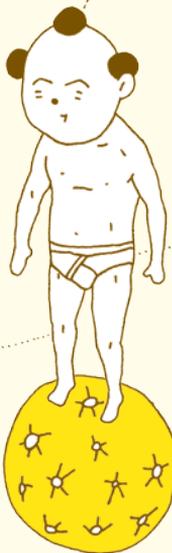
硒

Se



Used to make
windows for
skyscrapers

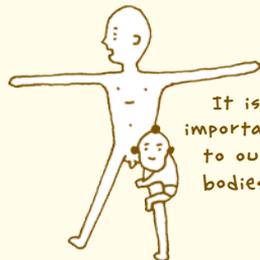
The oxygen
family



solid

mineral

selenium
means
"moon" in
greek.



It is
important
to our
bodies.



Japan produces
the most
selenium in
the world!

**GOOD AND EVIL,
THE ELEMENT WITH TWO FACES**

[sil:niəm]
DISCOVERY YEAR: 1817

Selenium is pretty smelly, as it belongs to the same family as sulfur, but it's a vital part of our metabolism. A selenium deficiency makes your immune system weaker, but if you take too much, it can damage your intestines and stomach! It's pretty easy to take in just the right amount, as shellfish, vegetables, beef, eggs, and many other foods contain selenium in small quantities. Selenium is also used in night-vision cameras.

MELTING POINT

217

°C

BOILING POINT

684.9

°C

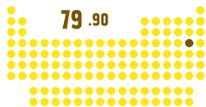
DENSITY

4.79

(GRAY SOLID)
g/cm³

35

臭素
Bromine



4
17

溴

Br



Used in
photography



Red liquid =
deadly poison



In seawater

**MORE ROMANTIC
THAN IT SOUNDS**

[bróumi:n]
DISCOVERY YEAR: 1826

The French chemist Antoine Jérôme Balard and the German chemist Carl Jacob Löwig each independently discovered bromine as students in 1826. Bromine dyes (extracted from certain species of snails) were sought after in ancient Japan and Europe for their beautiful color, a vivid purple. Silver bromide is also very sensitive to light, which has made it the basis of modern photography materials.

MELTING POINT

-7.3

°C

BOILING POINT

58.78

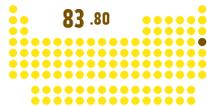
°C

DENSITY

3.1226

(LIQUID, 20°C)
g/cm³

36

クリプトン
Krypton

4

18

氪

Kr



The name of
superman's home
planet



THE BRIGHTLY SHINING FLASH-MAN

[kriptan]
DISCOVERY YEAR: 1898

Most people probably know that Superman's home planet is named Krypton, but the element's name actually comes from the word *cryptic*, as it was very hard to discover. Krypton light bulbs can be made very small and still outshine any argon-based counterpart, which makes them popular with photographers and filmmakers. Krypton is also used in stroboscopes, high-powered gas lasers, and many other applications.

MELTING POINT

-156.6

°C

BOILING POINT

-152.3

°C

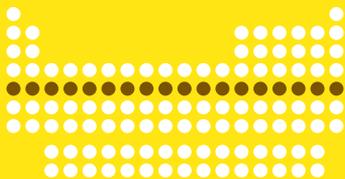
DENSITY

0.0037493
(GAS FORM, 20°C)
g/cm³

周期

PERIOD

5



原子番号

ATOMIC NUMBER

37 → 54

37



ルビジウム
Rubidium

38



ストロンチウム
Strontium

39



イットリウム
Yttrium

40



ジルコニウム
Zirconium

41



ニオブ
Niobium

42



モリブデン
Molybdenum

43



テクネチウム
Technetium

44



ルテニウム
Ruthenium

45



ロジウム
Rhodium

46



パラジウム
Palladium

47



銀
Silver

48



カドミウム
Cadmium

49



インジウム
Indium

50



スズ
Tin

51



アンチモン
Antimony

52



テルル
Tellurium

53



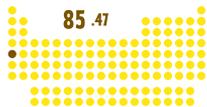
ヨウ素
Iodine

54



キセノン
Xenon

37

ルビジウム
Rubidium5
1

鉷如

Rb



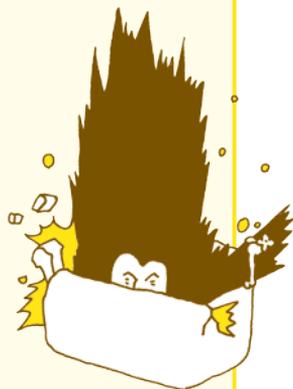
Used to
measure the
age of rocks



Used in cathode
ray tube glass



Atomic clocks made with
rubidium have a yearly
error of 0.1 seconds.



Explodes
violently if it
touches water

THE TIMEKEEPER OF THE UNIVERSE

[ru:bidium]
DISCOVERY YEAR: 1861

Tick tock. The atomic clock that controls the NHK time broadcasts* works by monitoring the energy fluctuations of a rubidium isotope and misses by only 1 second every 10 years or so. The half-life of rubidium is a whopping 48.8 billion years, perfect for assessing the age of Earth's minerals and asteroid remnants. This is done by measuring the rubidium left in the sample, then calculating how long it took to decay to that point.

MELTING POINT

39.1

°C

BOILING POINT

688

°C

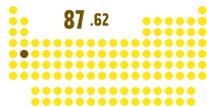
DENSITY

1.532

g/cm³

* NHK shows the current time in the corner of all its TV broadcasts.

38

ストロンチウム
Strontium5
—
2

锶

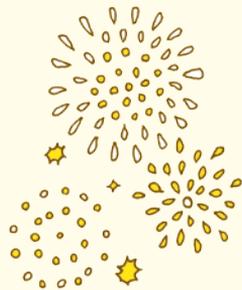
Sr



Fireworks

Specialist uses

Solid



The vivid red in fireworks

Pop

THE SWEET
FIREBALL DUDE[stránjiəm]
DISCOVERY YEAR: 1787

The scarlet explosions that stand out in any fireworks show are probably made of strontium. All alkali and alkaline earth metal elements burn with different colors, but strontium outshines the rest with its brilliant hue. It's also used in most commercial flares. It takes after its alkaline earth metal big brother, calcium, in that it is easily absorbed into bone. This is why it's also used for bone tumor treatments and diagnostic measures.

MELTING POINT

769

°C

BOILING POINT

1384

°C

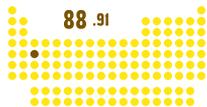
DENSITY

2.54

g/cm³

39

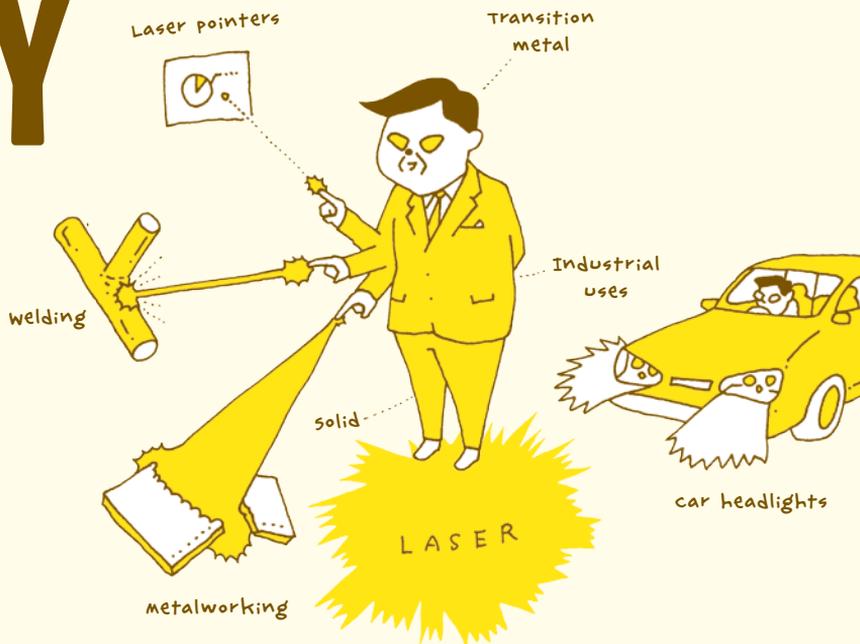
イットリウム
Yttrium



5
—
3

钇

Y



THE PIONEER OF THE LASER WORLD

[yttrium]
DISCOVERY YEAR: 1794

I'm guessing most of us played with pocket lasers as kids, but did you know that *laser* is an acronym that stands for "Light Amplification by Stimulated Emission of Radiation"? A mouthful, huh? Yttrium and aluminum oxides are used in the creation of YAG crystals, which are vital to the construction of solid-state lasers. They're used in factories and hospitals as welding and operating-room tools.

MELTING POINT

1522

°C

BOILING POINT

3338

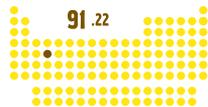
°C

DENSITY

4.469

g/cm³

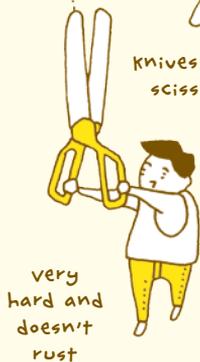
40

ジルコニウム
Zirconium5
—
4

锆

Zr

ceramics



knives and scissors

Transition metal



Solid



Here too

Multipurpose



In teeth



Almost indistinguishable from real diamonds



Atomic reactors

DIAMONDS FOR EVERYONE!

[zɔ:rkouniəm]
DISCOVERY YEAR: 1789

Zirconium shines as brightly as any diamond if processed correctly (as cubic zirconia). It can also be made into a rust-free ceramic material that's harder than steel if it's oxidized, ground into a powder, and sintered. These advanced ceramics can be used for creating useful household tools such as scissors and kitchen knives, as well as in more exotic applications like spacecraft and jet engines.

MELTING POINT

1852

°C

BOILING POINT

4377

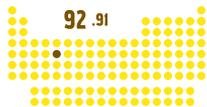
°C

DENSITY

6.506

g/cm³

41

ニオブ
Niobium5
—
5

铌

Nb

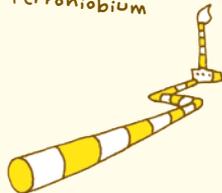
Iron

Niobium



strong

Ferroniobium



Used in pipelines

Transition
metal

Zero resistance

Industrial
usesSuperconductivity
occurs at low
temperatures.

solid

The magnets
used in
maglev trains

SUPPORTING THE PRACTICALITIES OF THE FUTURE

[naióubiəm]
DISCOVERY YEAR: 1801

Niobium is named after Niobe, the daughter of Tantalus in Greek myth, since it bears some resemblance to element 73 (tantalum). But despite the name's ancient origins, it now represents an element used in cutting-edge jet engines, space shuttles, and maglev vehicles. The metal can create extremely powerful magnetic materials by being alloyed with steel. This makes it not only heat resistant but also superconductive.

MELTING POINT

2468

°C

BOILING POINT

4742

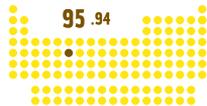
°C

DENSITY

8.57

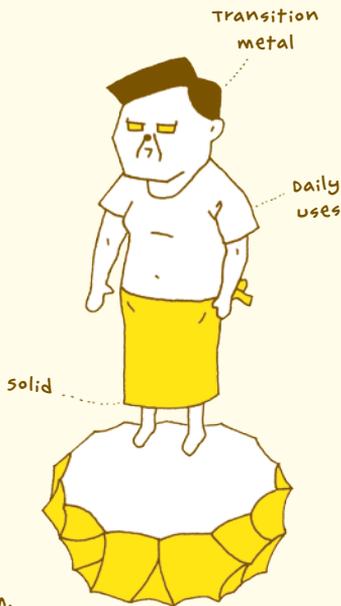
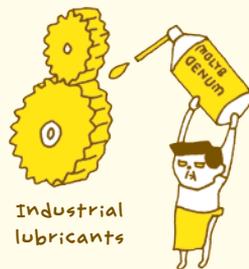
g/cm³

42

モリブデン
Molybdenum5
—
6

鉬

Mo

Ultra-modern
toilet seats

THE DIVERSE BLACKSMITH

[mølibdønəm]
DISCOVERY YEAR: 1778

Molybdenum steel is a very strong and rust-resistant iron alloy. Knives made from this steel can cost several hundred dollars. This specialist material is also used in jet plane landing gear and rocket engines. Recent research has enabled us to use molybdenum to heat water more effectively, creating a new generation of ceramic heaters (used in automated Japanese toilets, which use warm jets of water instead of toilet paper).

MELTING POINT

2617

°C

BOILING POINT

4612

°C

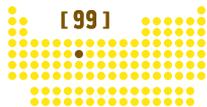
DENSITY

10.22

g/cm³

43

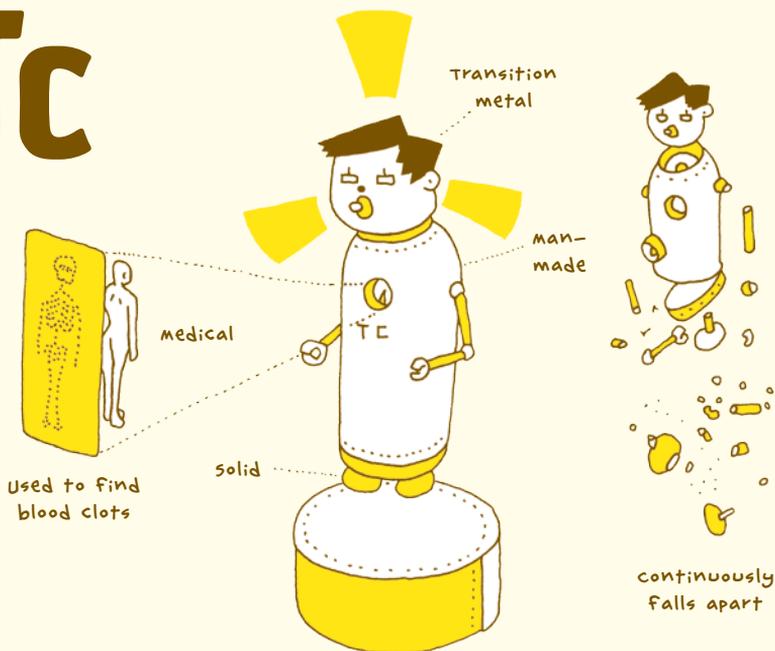
テクネチウム
Technetium



5
7

得

Tc



THE FIRST MAN-MADE ELEMENT

[teknɪːʃiəm]
DISCOVERY YEAR: 1936

While there might have been particles of the 43rd element at the time Earth was born, they have long since decayed. Scientists searched for this element for decades after Mendeleev predicted its existence. The element has many medical uses. For example, because the technetium-99m isotope decays very quickly, it is used as a radioactive tracer to perform imaging scans and detect blood clots.

MELTING POINT

2172

°C

BOILING POINT

4877

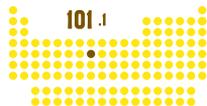
°C

DENSITY

11.5

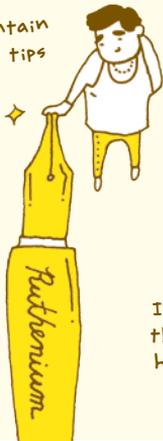
g/cm³

44

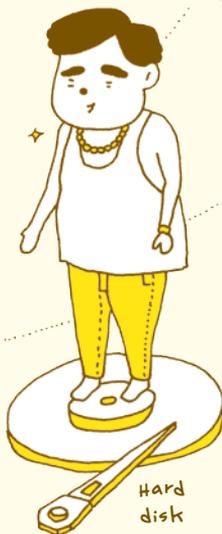
ルテニウム
Ruthenium5
—
8

釘

Ru

Fountain
pen tips

Solid

Increasing
the size of
hard disksTransition
metal

Multipurpose

Hard but
brittleGood at splitting
water into
hydrogen and
oxygen with the
help of sunlight

Light



A CELEBRITY SINCE BIRTH

[ru:θ:niəm]
DISCOVERY YEAR: 1844

While it hangs out with the other precious metals, ruthenium isn't really an accessory type of guy. However, it did contribute to two recent Nobel prizes (in 2001 and 2005) as a catalyst in organic synthetic chemistry. It's great for creating higher-capacity magnetic hard drives, and since it has a beautiful luster and is durable, it's also used for making fountain pens. An air of glamour hangs about this element.

MELTING POINT

2310

°C

BOILING POINT

3900

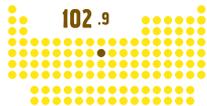
°C

DENSITY

12.37

g/cm³

45

ロジウム
Rhodium5
9

銩

Rh

Transition
metalIt's
actually
very rare.Specialist
uses

Solid

Perfectly
preservedAs a purifier
catalystFor polishing
jewelryALWAYS A BRIDESMAID,
NEVER A BRIDE[róudiəm]
DISCOVERY YEAR: 1803

Only 16 tons of this precious metal are produced every year. And even though it's of higher quality than both gold and platinum, it's never allowed up on the main stage. However, it does participate—it's used as a coating material. Its beautiful white color doesn't lose its shine over time, and it makes silver and platinum last longer when processed together. This admirable element supports others at the cost of its own fame.

MELTING POINT

1966

°C

BOILING POINT

3727

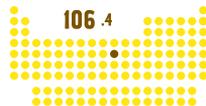
°C

DENSITY

12.41

g/cm³

46

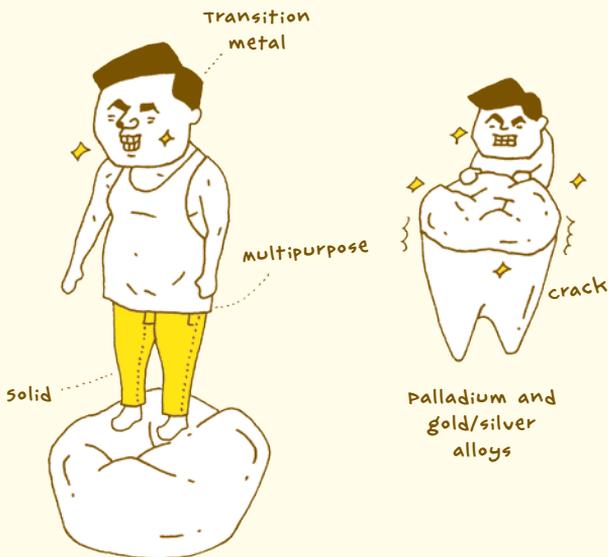
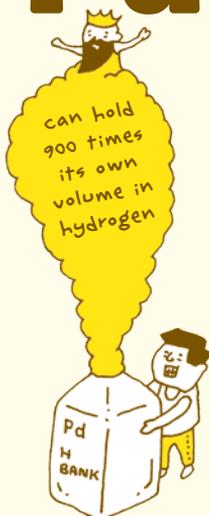
パラジウム
Palladium

5

10

钯

Pd



THE FORMER UGLY DUCKLING

[pələ́idiəm]
DISCOVERY YEAR: 1803

Long long ago, it was considered bad luck when a gold miner found a vein contaminated by palladium. The element was found about the same time that the asteroid Pallas was discovered and was therefore named after it. It is well liked by scientists as it can hold up to 900 times its own volume in hydrogen. Palladium is used in hydrogen fuel cells and as a catalyst when producing organic compounds. It's also used in dentistry.

MELTING POINT

1552

°C

BOILING POINT

3140

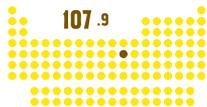
°C

DENSITY

12.02

g/cm³

47

銀
Silver5
II

銀

Ag

As accessories
and utensilssilver nitrate
compounds are
used in photo
paper.

For warding off demons

STYLISH AND GOOD AT
WHAT HE DOES[silver]
DISCOVERY YEAR: ANCIENT

Silver's shine evokes a romantic mood, and this metal is cheap and easy to work with. This makes it perfect for utensils and accessories. Silver ions are also particularly good at killing bacteria by destabilizing their enzymes, and silver's gaining ground as a component of deodorants and odor-resistant fibers. Its natural enemy is sulfur, which on contact makes silver go black. So don't wash your silverware in the local hot spring!

MELTING POINT

961.93

°C

BOILING POINT

2212

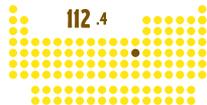
°C

DENSITY

10.5

g/cm³

48

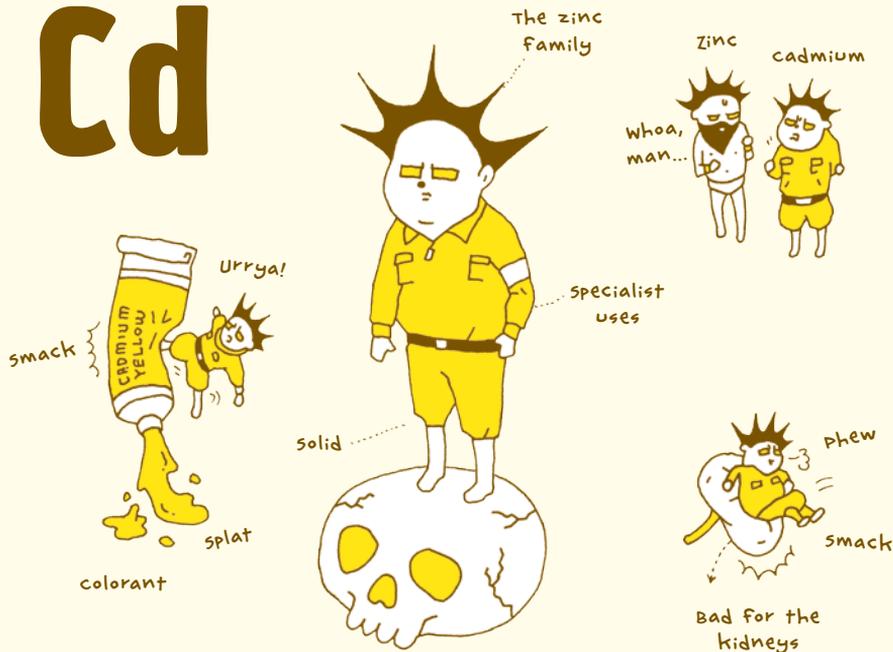
カドミウム
Cadmium

5

12

鎘

Cd



THE RAMPAGING MAD SCIENTIST

[kædmiəm]
DISCOVERY YEAR: 1817

A mysterious sickness that spread near the Jinzuu River from 1912 to 1946 became known as one of the four big pollution diseases of Japan and was called the *itai-itai* ("ouch-ouch") disease. It was caused by cadmium from a mine upstream. Since it's very similar in structure to zinc, cadmium can enter the body, where it eventually weakens bones and obstructs the kidneys. Uses include pigments and nickel-cadmium batteries.

MELTING POINT

320.9

°C

BOILING POINT

765

°C

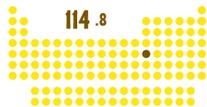
DENSITY

0.00865

(25°C)

g/cm³

49

インジウム
Indium

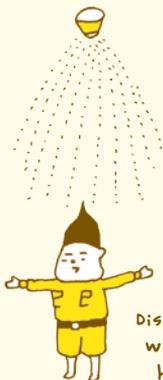
5

13

鋼

In

sprinkler systems

Dissolves
well in
heatThe boron
familycommonly
recycledspecialist
uses

solid



LCDs

Most of it is
produced in
China.HE'S IN SEASON!
THE HERO OF THE DAY[indium]
DISCOVERY YEAR: 1863

Indium is indispensable to electronics manufacturers, as it's used for making flat-screen TVs. Its unusual quality of being able to create transparent and conductive films is vital for making all types of LCD, plasma, and OLED* displays. Japan was once the world's largest producer of indium, but since the mine shut down in 2006, people are now scrambling to enact indium recycling programs all over the world.

MELTING POINT

156.17

°C

BOILING POINT

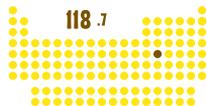
2080

°C

DENSITY

7.31
(25°C)g/cm³

50

スズ
Tin5
—
14

锡

Sn



Tin cans
are made
of iron and
tin plates.



Toys

Buddha
statuessolder is a
lead and tin
alloy.THE HERO OF OLD
TURNED SLACKER[tin]
DISCOVERY YEAR: ANCIENT

Tin is abundant, easy to work with, and has a low melting point. Its alloy with copper, bronze, has been used throughout history to make swords and spear tips. It has also been used in Japan since the Nara period for building Buddha statues. Despite having been used to make almost everything, it has few uses left. It can still be found in tin model toys, tin cans, solder, and printing equipment, though.

MELTING POINT

231.9681

°C

BOILING POINT

2270

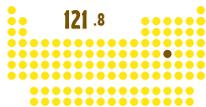
°C

DENSITY

7.31

(WHITE TIN)
g/cm³

51

アンチモン
Antimony

5

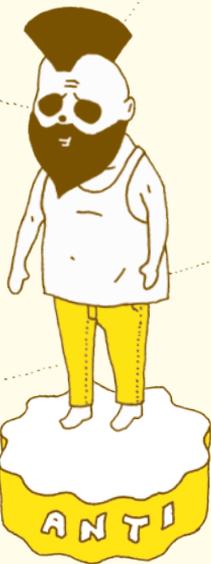
15

銻

Sb

Cleopatra's
makeup

Poison

The nitrogen
family

Multipurpose

Used in
linotype
machinesMakes things
harder to burn

CLEOPATRA'S DARLING

[æntəmòuni]
DISCOVERY YEAR: 1450

You don't see it often these days, but antimony is used in some semiconductors and in the poles of lead batteries. It's also used together with lead in printing equipment and is steadily gaining ground in other areas. In ancient Egypt antimony sulfide (as kohl) was Queen Cleopatra's eyeliner of choice—a pretty glamorous past for such a steady worker. I wouldn't recommend using it the same way now, though, as it's rather toxic.

MELTING POINT

630.74

°C

BOILING POINT

1635

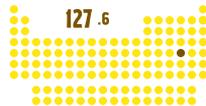
°C

DENSITY

6.691

g/cm³

52

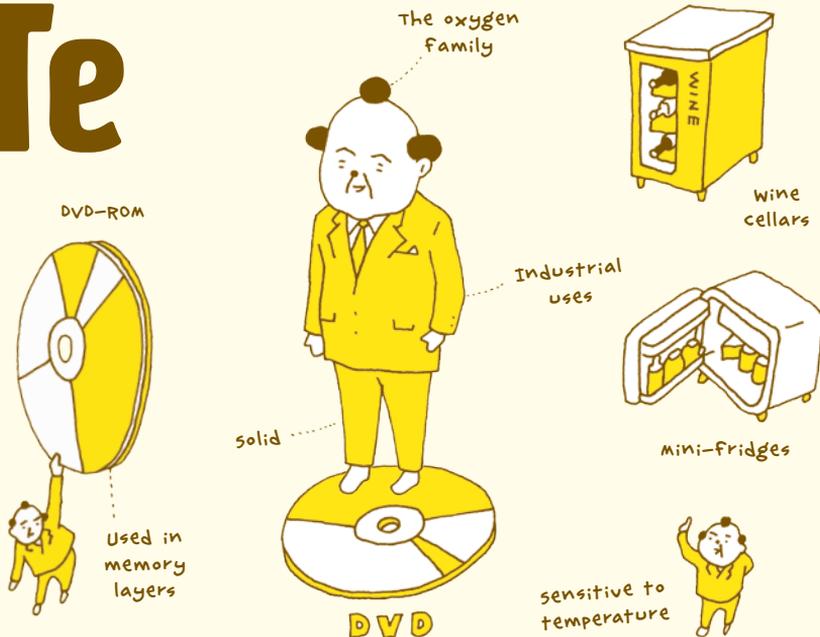
テルル
Tellurium

5

16

碲

Te



THE CUTE BUT SMELLY ELEMENT

[telúəriəm]
DISCOVERY YEAR: 1782

The quaint-sounding element tellurium is named after the Latin word for our planet, *Tellus*, and is used in everything from DVD data recording to green LEDs. It's also great for making quiet and versatile mini-fridges when compounded with bismuth and selenium. It can be alloyed with iron, copper, and lead to make these metals easier to work with. It's too bad that it smells like garlic, which makes it a bit hard to be around.

MELTING POINT

449.5

°C

BOILING POINT

990

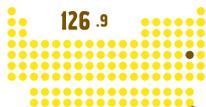
°C

DENSITY

6.24

g/cm³

53

ヨウ素
Iodine

5

17

碘

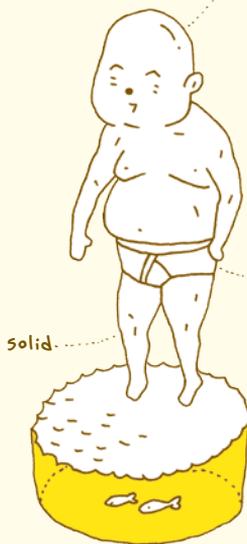
Iodine mouthwash



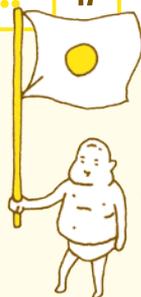
Disinfectant



Halogen



mineral

Japan is
a leading
producer.

**BORN FROM SEAWEED
AND RAISED IN THE
CHIBA PREFECTURE**

[áièdàin]

DISCOVERY YEAR: 1811

Iodine is a vital mineral that can be found in our thyroid gland hormones. The Minami Kanto gas field in the Chiba prefecture is one of the largest producers of iodine in the world, second only to Chile. The silver iodide compound can be used in a process called *cloud seeding* to artificially produce rain. This method was actually used in Tokyo during the bone-dry summers of 1996 and 2001.

MELTING POINT

113.6

°C

BOILING POINT

184.4

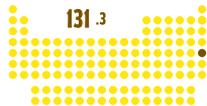
°C

DENSITY

4.93

g/cm³

54

キセノン
Xenon

5

18

氙

Xe

xenon lamps

Almost as strong
as sunlight

Noble gas



Gaseous

Industrial
usesspace
explorersIon engine
propellant

THE RISING GAS THAT TRAVELS AMONG THE STARS

[zi:nan]
DISCOVERY YEAR: 1898

The NASA New Millennium program *Deep Space 1* spacecraft, the European Space Agency's *SMART-1*, and the Japanese asteroid probe *Hayabusa* all have one thing in common: Their engines ran on xenon fuel. Xenon engines are about 10 times as fuel effective as their rocket engine counterparts. Xenon is also used as the active gas in plasma displays and as a general anesthetic. Xenon is on the rise!

MELTING POINT

-111.9

°C

BOILING POINT

-107.1

°C

DENSITY

0.0058971
(GAS FORM, 20°C)
g/cm³

周期

PERIOD

6



原子番号

ATOMIC NUMBER

55 → 86

55

セシウム
Cesium

56

バリウム
Barium

57

ランタン
Lanthanum

58

セリウム
Cerium

59

プラセオジウム
Praseodymium

60

ネオジウム
Neodymium

61

プロメチウム
Promethium

62

サマリウム
Samarium

63

ユーロピウム
Europium

64

ガドリニウム
Gadolinium

65

テルビウム
Terbium

66

ジスプロシウム
Dysprosium

67

ホルミウム
Holmium

68

エルビウム
Erbium

69

ツリウム
Thulium

70

イッテルビウム
Ytterbium

71

ルテチウム
Lutetium

72

ハフニウム
Hafnium

73

タンタル
Tantalum

74

タングステン
Tungsten

75

レニウム
Rhenium

76

オスミウム
Osmium

77

イリジウム
Iridium

78

白金
Platinum

79

金
Gold

80

水銀
Mercury

81

タリウム
Thallium

82

鉛
Lead

83

ビスマス
Bismuth

84

ポロニウム
Polonium

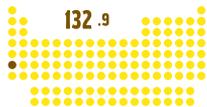
85

アスタチン
Astatine

86

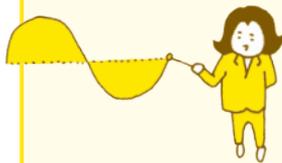
ラドン
Radon

55

セシウム
Cesium6
—
1

铯

Cs



The period of its
electromagnetic
wave * 9,192,631,770
= 1 second



Japan's standard
time runs on a
cesium-based
atomic clock.



SECOND TO NONE

[sɪːziəm]
DISCOVERY YEAR: 1860

Have you ever wondered why one second is one second long? Earth's rotational speed was used until 1967, when the General Conference on Weights and Measures decided that the second should be further defined. This is when cesium came into the picture. Now the second is a multiple of the period of cesium's electromagnetic wave. Atomic clocks based on this measurement miss only one second every 1.4 million years.

MELTING POINT
28.40

°C

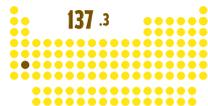
BOILING POINT
668.5

°C

DENSITY
1.873

g/cm³

56

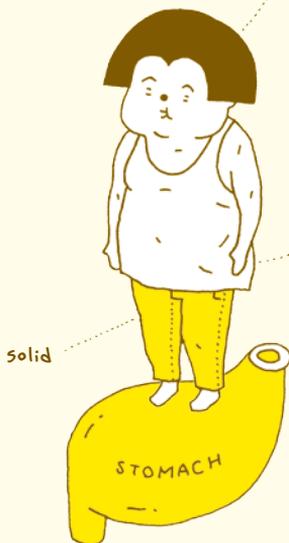
バリウム
Barium6
—
2

钡

Ba



Used in
contrast
fluids for
X-rays



solid

Alkaline
earth metal

Multipurpose



stops X-rays

**A DOCTOR AT WORK,
A GANGSTER AT HOME**

[béəriəm]

DISCOVERY YEAR: 1808

The white liquid you have to drink before some X-ray procedures is a solution consisting of a powder called barium sulfate and water. It's perfect for analyzing the gastrointestinal tract because X-rays won't pass through it. However, dissolving barium ions in water creates a very strong poison that causes vomiting and paralysis. Pure metallic barium reacts violently when exposed to air, so it's usually preserved in oil.

MELTING POINT
729

°C

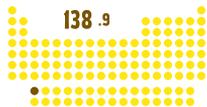
BOILING POINT
1637

°C

DENSITY
3.594

g/cm³

57

ランタン
Lanthanum6
3

镧

La

Lanthanide

Used in
telescope
lenses $LaNi_5$ An alloy
that
absorbs
hydrogenIndustrial
uses

solid

mobile
camera
lensesTHE LEADER OF THE
OUTSIDERS

[læŋθəniəm]

DISCOVERY YEAR: 1839

The next 14 elements are all similar to lanthanum in both their properties and application areas, which is why they (and lanthanum) are grouped together as the lanthanide family. Though some of the other lanthanides are magnetic, lanthanum isn't. It's used as the flint in lighters, in the lenses of mobile cameras, and as a medication to help prevent renal failure.

MELTING POINT
921

°C

BOILING POINT
3457

°C

DENSITY
6.145
(25°C)g/cm³

58

セリウム
Cerium

[sɛriəm]

DISCOVERY YEAR: 1803

Ce

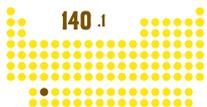
Lanthanide

Daily uses

solid

THE MAINSTAY OF THE
LANTHANIDES

铈



6

MELTING POINT
799 °CBOILING POINT
3426 °C

3

DENSITY (SOLID)
(25°C) 6.749 g/cm³

More naturally abundant than copper or silver, cerium is used in sunglasses and UV-resistant glass for its ability to absorb ultraviolet rays. It's also used in engines as a purification catalyst.

59

プラセオジウム
Praseodymium

[prɛziouðimíəm]

DISCOVERY YEAR: 1885

Pr

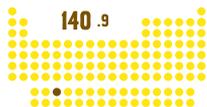
Lanthanide

Specialist
uses

solid

THE FLAMING YELLOW
MAGICIAN

镨



6

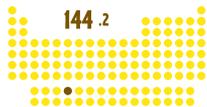
MELTING POINT
931 °CBOILING POINT
3512 °C

3

DENSITY
6.773 g/cm³

Pure praseodymium is a silver-white solid, but it turns yellow when oxidized. It's often used in welding goggles because it absorbs blue light. Its beautiful yellow is also used in pottery enamel.

60

ネオジム
Neodymium

144.2

6

3

钕

Nd

Lanthanide



MRI magnets



smack

S



solid

magnetic

Hybrid car
motorsmobile
phone
vibrators

shake

shake

THE WORLD'S STRONGEST
SUPER MAGNET

[ni:oudimiəm]

DISCOVERY YEAR: 1885

The twin brother of praseodymium was found in the same piece of rock and was consequently named neodymium, which means “the new twin.” But one should not take the younger twin lightly! Neodymium, when alloyed with iron and a few other elements, produced the world’s strongest magnet in 1982. This new type of magnet was about 1.5 times as strong as the previous record holder and became instantly famous.

MELTING POINT

1021

°C

BOILING POINT

3068

°C

DENSITY

7.007

g/cm³

61

プロメチウム
Promethium

[prəmi:θiəm]
DISCOVERY YEAR: 1926

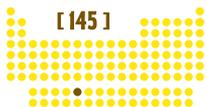
Pm

Lanthanide



THE FIERY CHILD
BORN IN OUR REACTORS

鉬



6

MELTING POINT
1168 °C

BOILING POINT
APPROX. 2727 °C

3

DENSITY
7.22 g/cm³

The only man-made radioactive lanthanide element is named after the Titan who gave humanity fire: Prometheus. Born in our atomic reactors, it produces heat that's perfect for powering nuclear cells.

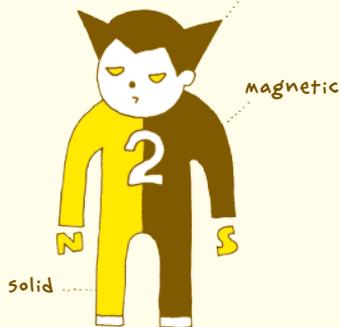
62

サマリウム
Samarium

[səmə'riəm]
DISCOVERY YEAR: 1879

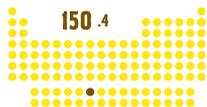
Sm

Lanthanide



NUMBER TWO IN THE WORLD
OF MAGNETISM

釷



6

MELTING POINT
1077 °C

BOILING POINT
1791 °C

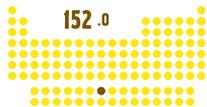
3

DENSITY
7.52 g/cm³

The samarium-cobalt magnet was champion before neodymium claimed the title of world's strongest magnet. Even small lanthanide magnets are exceptionally strong, so they're often used in earphones.

63

ユウロピウム
Europium



6
—
3

销

Eu

Lanthanide



The red display
elements of
CRT screens

Industrial
uses



Highlights
immune system
responses



In
luminescent
paint

Solid



**A RESIDENT OF THE NIGHT,
LIGHTING UP THE DARK**

[juə'róupiəm]

DISCOVERY YEAR: 1896

It's the element glowing faintly inside watches and alarm clocks everywhere. It's also used in luminous paint and as an anticounterfeiting measure in euro banknotes. (How appropriate!) But most of the world's europium comes from the US and China. Europium is also in charge of the red component in fluorescent lights and the red display elements in CRT TVs.

MELTING POINT
822

°C

BOILING POINT
1597

°C

DENSITY
5.243

g/cm³

64

ガドリニウム
Gadolinium

[gædəlɪniəm]

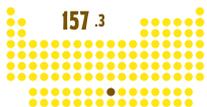
DISCOVERY YEAR: 1886

Gd

Lanthanide

FINDING ILLNESS WITH THE HELP
OF MAGNETISM!

钆



6

MELTING POINT
1313 °CBOILING POINT
3266 °C

3

DENSITY (25°C)
7.9004 g/cm³

Gadolinium is a component of the contrast agent used in most MRI examinations, and it's also in nuclear reactors because of its ability to absorb emitted neutrons well.

65

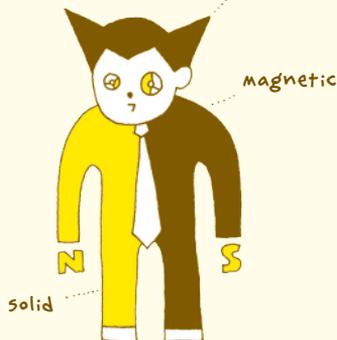
テルビウム
Terbium

[tɛːrbiəm]

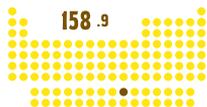
DISCOVERY YEAR: 1843

Tb

Lanthanide

THE OVERLOOKED MAGNET
OF YESTERYEAR

铽



6

MELTING POINT
1356 °CBOILING POINT
3123 °C

3

DENSITY
8.229 g/cm³

Terbium is used in actuators, sonar systems, and fluorescent lamps. It's also used in electric bicycles and magnetic glass due to its magnetic properties.

66

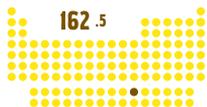
ジスプロシウム
Dysprosium[dispróusiam]
DISCOVERY YEAR: 1886

Dy

Lanthanide

THE STRONGEST TAG TEAM!
DYSPROSIUM AND NEODYMIUM

鎳



6

MELTING POINT
1412 °C

3

BOILING POINT
2562 °CDENSITY
8.55 g/cm³

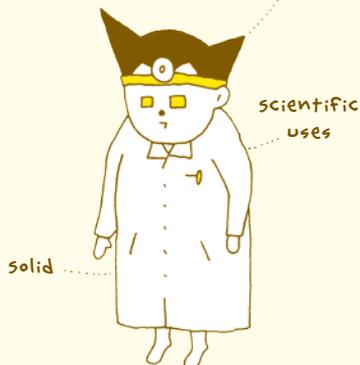
Even the strongest neodymium magnet weakens when heated. That's where dysprosium comes in. This combination is essential in places where high temperatures are the norm, like hybrid car engines.

67

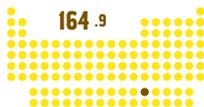
ホルミウム
Holmium[hólumiam]
DISCOVERY YEAR: 1879

Ho

Lanthanide

A PAL TO PROSTATES
EVERYWHERE

鈇



6

MELTING POINT
1474 °C

3

BOILING POINT
2395 °CDENSITY
8.795 g/cm³

Holmium lasers are a perfect treatment method for prostatic hypertrophy. The laser prevents hemorrhage as the incision is performed. It is also great for removing renal and urethral stones.

68

エルビウム
Erbium

[ér:biəm]

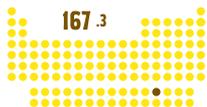
DISCOVERY YEAR: 1843

Er

Lanthanide

MANAGING OUR WORLDWIDE
NETWORKS

铒



167.3

6

MELTING POINT
1529 °CBOILING POINT
2863 °C

3

DENSITY (25°C)
9.066 g/cm³

When we send data over the Internet, we're sending it as light pulses through long, reflecting cables; doing this over long distances would be impossible without erbium light-amplification relays.

69

ツリウム
Thulium

[θj:liəm]

DISCOVERY YEAR: 1879

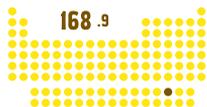
Tm

Lanthanide



ERBIUM'S LITTLE BROTHER

铥



168.9

6

MELTING POINT
1545 °CBOILING POINT
1947 °C

3

DENSITY
9.321 g/cm³

Thulium is still not used much in industry due to being very rare and very hard to isolate. It is, however, much like erbium, used in optic fiber light-amplification units.

70

イッテルビウム
Ytterbium

[itɛːrbiəm]

DISCOVERY YEAR: 1878

Yb

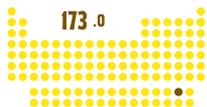
Lanthanide

specialist
uses

solid

ANOTHER ONE FROM
TEAM SCANDINAVIA

鏡



6

MELTING POINT
824 °C

3

BOILING POINT
1193 °C

DENSITY
6.965 g/cm³

Its name comes from Ytterby, a small town in Sweden where a multitude of elements have been discovered. Ytterbium's uses are very similar to those of erbium, and it can color glass yellow-green.

71

ルテチウム
Lutetium

[lɜːtɪːʃiəm]

DISCOVERY YEAR: 1907

Lu

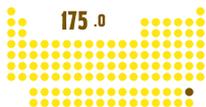
Lanthanide

specialist
uses

solid

MORE EXPENSIVE THAN GOLD!
THE ROYAL ELEMENT

鑷



6

MELTING POINT
1663 °C

3

BOILING POINT
3395 °C

DENSITY
9.84 g/cm³

It's hard to believe, but lutetium costs a whopping ¥50,500* per gram! That's more than the price of silver, gold, and platinum combined. It doesn't really have any applications outside of research, though.

72

ハフニウム
Hafnium

[háefnióm]

DISCOVERY YEAR: 1922

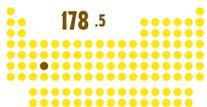
Hf

Transition
metalspecialist
uses

solid

ZIRCONIUM'S
SIGNIFICANT OTHER

铪



6

MELTING POINT
2230 °CBOILING POINT
5197 °C

4

DENSITY
13.31 g/cm³

With properties very similar to zirconium's, hafnium is sometimes used in nuclear reactor control rods to absorb neutrons, while zirconium takes the opposite role of the reactor's fuel rods.

73

タンタル
Tantalum

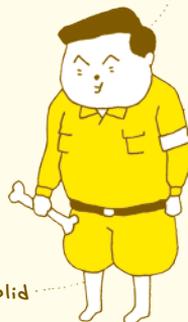
[tántalem]

DISCOVERY YEAR: 1802

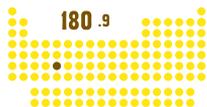
Ta

Transition
metalspecialist
uses

solid

FOR BONE PROSTHESES AND
MOBILE PHONES

钽



6

MELTING POINT
2996 °CBOILING POINT
5425 °C

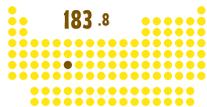
5

DENSITY
16.654 g/cm³

Since the human body tolerates tantalum well, it is often used for bone prostheses, artificial joints, and dental implants. It's also used in small, efficient electric capacitors for mobile phones and laptops.

74

タングステン
Tungsten



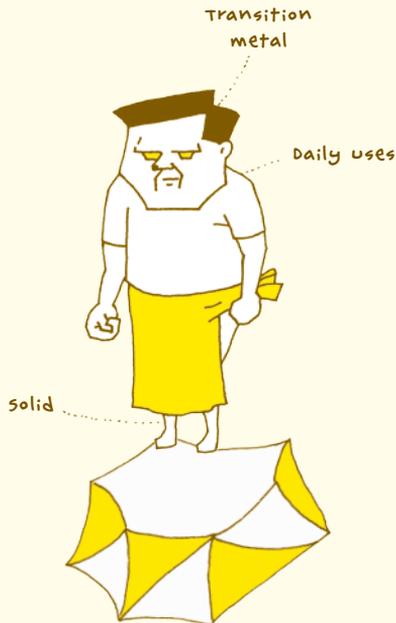
6
6

钨

W



As the filament in
lightbulbs



Drill bits



Forms extremely
strong steel
with carbon

THE WORLD'S MOST THICK- SKINNED ARTISAN

[tʌŋstən]

DISCOVERY YEAR: 1781

When Edison invented the light bulb, he used a piece of wick as his filament, but it burned too fast to be useful and broke easily. In the 20th century, we began using tungsten to make filaments, and thus the tungsten halogen lamp was born. Tungsten has the highest melting point of all the elements. When carbonized, it produces a super material that's almost as hard as diamond and is used to make abrasion-resistant drills and molds.

MELTING POINT

3407

°C

BOILING POINT

5657

°C

DENSITY

19.3

g/cm³

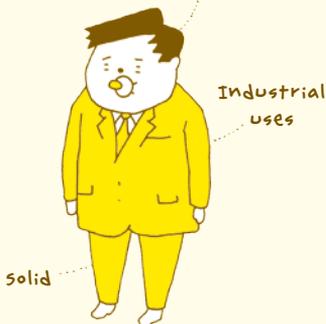
75

レニウム
Rhenium

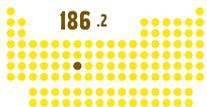
[ri:niəm]

DISCOVERY YEAR: 1925

Re

Transition
metalOUR MOST RECENT
NATURAL FIND

铼



6

MELTING POINT
3180 °CBOILING POINT
5627 °C

7

DENSITY
21.02 g/cm³

Rhenium is our most recent natural find. It has the second-highest melting point, just below that of tungsten. This makes it ideal for high-temperature measuring equipment and rocket nozzles.

76

オスミウム
Osmium

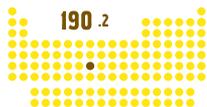
[ɑ:zmiəm]

DISCOVERY YEAR: 1803

Os

Transition
metalTHE HEAVIEST SUMO
OF THEM ALL

鐵



6

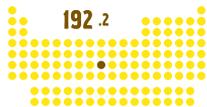
MELTING POINT
3054 °CBOILING POINT
5027 °C

8

DENSITY
22.59 g/cm³

The densest element and the heaviest metal, osmium becomes very abrasion- and rust-resistant when alloyed with iridium, ruthenium, and platinum. Its durability suits it for fountain pen tips.

77

イリジウム
Iridium6
9

銀

Ir



spark plugs are made of iridium alloys.



Iridium deposits in Earth's crust support the theory that the extinction of the dinosaurs was caused by a meteorite.



Until 1960, the international prototype meter was made out of a platinum and iridium alloy.

THE ELEMENT CLOSEST TO ETERNITY

[iridium]

DISCOVERY YEAR: 1803

Gold and platinum are well known for being used to make wedding rings and other jewelry because of their nonreactive natures, but the most resilient metal of all is actually iridium. Because of this, the international prototype kilogram is made of an alloy of about 10% iridium and 90% platinum, as was the international prototype meter until 1960. If you would like to swear an oath for eternal love, iridium might be your best bet.

MELTING POINT

2410

°C

BOILING POINT

4130

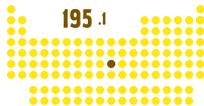
°C

DENSITY

22.56

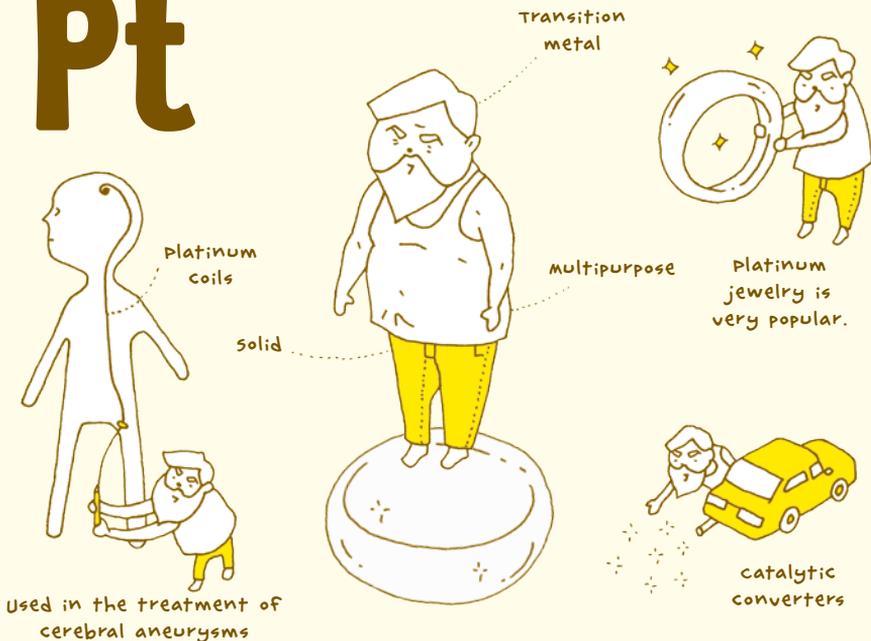
g/cm³

78

白金 (プラチナ)
Platinum6
—
10

铂

Pt

THE LATE-BLOOMING
STAR[plætənəm]
DISCOVERY YEAR: 1751

Platinum is popular now, but it played second fiddle to its older siblings gold and silver when it was discovered in the 18th century. Its name even means “small silver” in Spanish (*platina*). But today, due to its exceptional corrosion resistance, it’s used in jewelry, electrodes in physical and chemical science, and coils for treating cerebral aneurysms. It’s also a key part of some cancer-fighting drugs.

MELTING POINT
1772

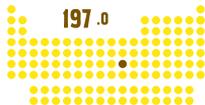
°C

BOILING POINT
3827

°C

DENSITY
21.45g/cm³

79

金
Gold

197.0

6

11

金

Au



False teeth

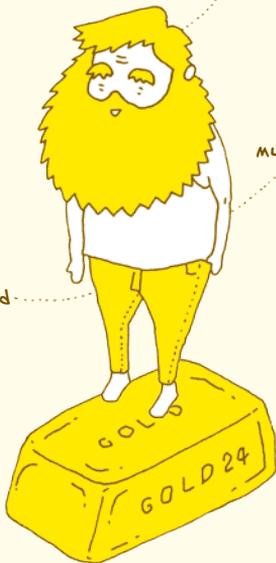
Transition
metalvery
malleable

Multipurpose

money



solid

I'm in
love!Heh
heh

**THE SYMBOL OF PROSPERITY,
WEALTH, AND POWER**

[góuld]

DISCOVERY YEAR: ANCIENT

Gold has always been a symbol of power, from King Tutankhamun's golden mask to the gleaming teeth of hip-hop mainstay Flavor Flav. In the Middle Ages, alchemists tried to create gold from other metals; their efforts served as a precursor to modern chemistry. Gold is also used in circuitry because of its excellent heat and electrical conductivity and in medals and coins for its beauty and corrosion resistance.

MELTING POINT
1064.43

°C

BOILING POINT
2807

°C

DENSITY
19.32

g/cm³

80

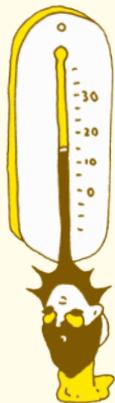
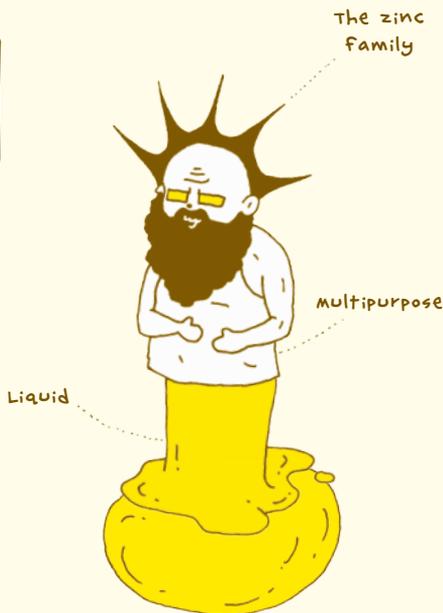
水銀
Mercury

200.6

6
12

汞

Hg

In older
thermometers

Liquid

Multipurpose

The zinc
family

Roll roll

very high
surface tension

Poisonous

THE MUTANT OF THE
METAL WORLD

[mó:rkjuri]

DISCOVERY YEAR: ANCIENT

Mercury is the only metal to be in liquid form and capable of evaporating at room temperature. It creates soft alloys (amalgams) when combined with other metals and has been used as plating for many years. It is still popular in thermometers and mercury vapor lamps. It is important to remember that while it may be easy to work with, it is highly toxic and can become a double-edged sword if one is not careful.

MELTING POINT

-38.87

°C

BOILING POINT

356.58

°C

DENSITY

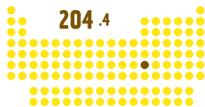
13.546

(LIQUID, 20°C)
g/cm³

81

タリウム

Thallium



6

13

鉈

TI



Used in nuclear
cardiography



**WITH THE UNEXPECTED
ABILITY TO DETECT
HEART ATTACKS**

[θæliəm]

DISCOVERY YEAR: 1861

Thallium is known for being almost as toxic as arsenic. A single gram is enough to kill an adult. It was the British serial killer Graham Young's murder weapon of choice and also appeared in Agatha Christie's *The Pale Horse*. It was also widely used as a rat and ant poison until the 1970s, when this use was prohibited for obvious reasons. More helpfully, it is used as a radioactive isotope to help us find irregular blood flows and the like.

MELTING POINT
303.5

°C

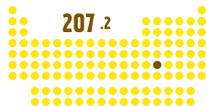
BOILING POINT
1457

°C

DENSITY
11.85

g/cm³

82

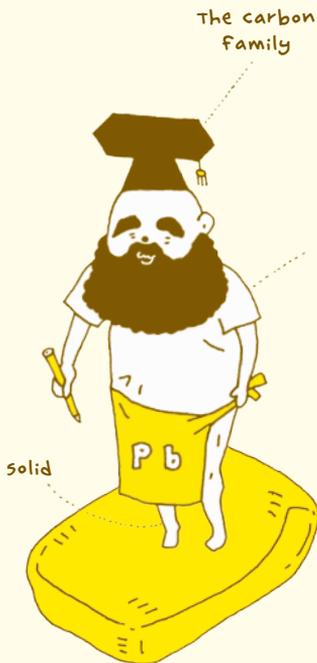
鉛
Lead

6

14

鉛

Pb

Doesn't let
radiation through

Daily uses

Fishing
sinker

In solder



**THE WORLD AUTHORITY
WHO WAS FORCED INTO
EARLY RETIREMENT**

[led]

DISCOVERY YEAR: ANCIENT

Lead is easy to work with and has had many uses over the years. The ancient Romans used it to build their waterways, but since it's a strong poison, that might have played a role in the fall of the Roman Empire. The word *plumbing* and the abbreviation *Pb* come from the Latin word for lead. Modern uses include car batteries, solder, and mirrors, but because of its toxicity and limited reserves, lead is being phased out of many applications.

MELTING POINT

327.50

°C

BOILING POINT

1740

°C

DENSITY

11.35

g/cm³

83

ビスマス
Bismuth

[bizməθ]

DISCOVERY YEAR: 1753

Bi

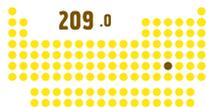
The nitrogen
familyDaily
uses

solid



LEAD'S FAITHFUL SUCCESSOR

秘



6

MELTING POINT
271.3 °C

BOILING POINT
1560 °C

15

DENSITY
9.747 g/cm³

Bismuth is useful both in alloys and in medical applications, such as remedies for gastric ulcers and diarrhea. Since it's similar to lead, it's gaining popularity as a nontoxic lead replacement.

84

ポロニウム
Polonium

[pəlouniəm]

DISCOVERY YEAR: 1898

Po

The oxygen
family

Radioactive

Specialist
uses

solid

THE MOST DESTRUCTIVE OF THE
NATURAL ELEMENTS

針



6

MELTING POINT
254 °C

BOILING POINT
962 °C

16

DENSITY
9.32 g/cm³

The naturally radioactive element polonium was the first element to be discovered by the Curies, with a radioactive intensity about 330 times as strong as that of uranium.

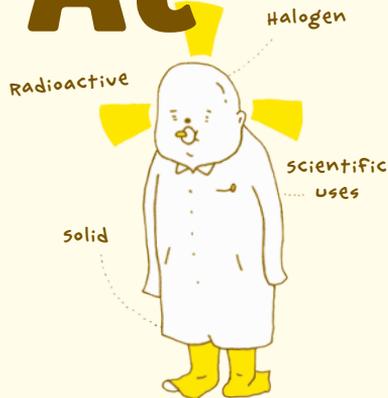
85

アスタチン
Astatine

[æstə'ti:n]

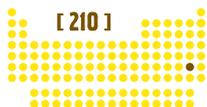
DISCOVERY YEAR: 1940

At



THE LAST SAMURAI OF
THE HALOGENS

砒



[210]

6

MELTING POINT
302 °C

BOILING POINT
337 °C

17

DENSITY
... g/cm³

Naturally occurring astatine is the most rarely encountered element in nature and has to be synthesized in order to be studied. Determining its properties is very hard because its half-life is so short.

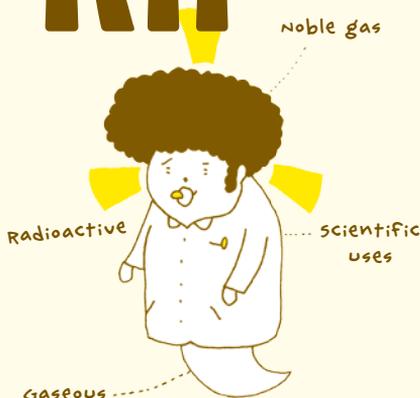
86

ラドン
Radon

[réidan]

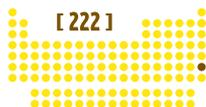
DISCOVERY YEAR: 1900

Rn



THE CHUBBY BATHING BEAUTY

気



[222]

6

MELTING POINT
-71 °C

BOILING POINT
-61.8 °C

18

DENSITY (GAS, 0°C)
0.00973 g/cm³

Radon is the heaviest gaseous element at room temperature. Hot springs containing radon are said to have a positive effect on any bather's health, but breathing radon can cause lung cancer.

周期

PERIOD

7



原子番号

ATOMIC NUMBER

87 → 118

87



フランシウム
Francium

88



ラジウム
Radium

89



アクチニウム
Actinium

90



トリウム
Thorium

91



プロトアクチニウム
Protactinium

92



ウラン
Uranium

93



ネプツニウム
Neptunium

94



プルトニウム
Plutonium

95



アメリシウム
Americium

96



キュリウム
Curium

97



バークリウム
Berkelium

98



カリホルニウム
Californium

99



アインスタイニウム
Einsteinium

100



フェルミウム
Fermium

101



メンデレビウム
Mendelevium

102



ノーベリウム
Nobelium

103



ローレンシウム
Lawrencium

104



ラザフォージウム
Rutherfordium

105



ドブニウム
Dubnium

106



シーボーギウム
Seaborgium

107



ボーリウム
Bohrium

108



ハッシウム
Hassium

109



マイトネリウム
Meitnerium

110



ダームスタチウム
Darmstadtium

111



レントゲニウム
Roentgenium

112



コペルニシウム
Copernicium

113



ウンウントリウム
Ununtrium

114



フレロビウム
Flerovium

115



ウンウンペンチウム
Ununpentium

116



リバモリウム
Livermorium

117



ウンウンセプチウム
Ununseptium

118



ウンウンオクチウム
Ununoctium

87

フランシウム
Francium

[frænsiəm]

DISCOVERY YEAR: 1939

Fr

Alkali metal

Radioactive

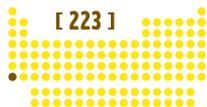
Scientific
uses

solid



THE FLEETING MYSTERY

𨭉



7

MELTING POINT
27 °CBOILING POINT
677 °C

1

DENSITY
... g/cm³

Francium has the shortest half-life of all naturally occurring radioactive elements at about 22 minutes. It is thought that the element is solid at room temperature, but that is still under debate.

88

ラジウム
Radium

[réidiəm]

DISCOVERY YEAR: 1898

Ra

Alkaline
earth metal

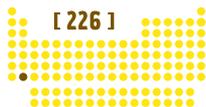
Radioactive

Specialist
uses

solid

THE ELEMENT THAT BIT THE
HAND THAT FED IT

𨭉



7

MELTING POINT
700 °CBOILING POINT
1140 °C

2

DENSITY
APPROX. 5 g/cm³

This element was discovered by Marie Curie in 1898. She received the Nobel prize in chemistry 1911 for her work but died a few decades later from ailments brought on by prolonged exposure to radiation.

89	アクチニウム Actinium	
Ac	Actinide Radio-active Solid scientific uses	錒
THE FIRST ACTINIDE		
[227]	7	MELTING POINT 1047 °C
	3	BOILING POINT 3197 °C
		DENSITY 10.06 g/cm ³



91	プロトアクチニウム Protactinium	
Pa	Actinide Radio-active Solid Industrial uses	釷
DISCOVERED BY TWO LEGENDARY SCIENTISTS*		
231.0	7	MELTING POINT 1840 °C
	3	BOILING POINT 4030 °C
		DENSITY 15.37 g/cm ³



* Germany's Otto Haan and Lise Meitner

90	トリウム Thorium	
Th	Actinide Radio-active Solid specialist uses	釷
HOLDS GREAT PROMISE AS THE FUEL OF TOMORROW		
232.0	7	MELTING POINT 1750 °C
	3	BOILING POINT 4787 °C
		DENSITY 11.72 g/cm ³



92	ウラン Uranium	
U	Actinide Radio-active Solid Industrial uses	鈾
FOR NUCLEAR POWER PLANTS AND ATOMIC BOMBS		
238.0	7	MELTING POINT 1132.3 °C
	3	BOILING POINT 3745 °C
		DENSITY 18.95 g/cm ³



93

ネプツニウム Neptunium

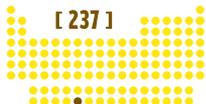
Np

Actinide
Radioactive
solid
man-made



鎗

EVEN HEAVIER THAN
URANIUM



7

MELTING POINT
640 °C

BOILING POINT
3902 °C

3

DENSITY
20.25 g/cm³

95

アメリシウム Americium

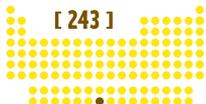
Am

Actinide
Radio-
active
solid
man-made



鍬

USED IN SMOKE DETECTORS



7

MELTING POINT
1172 °C

BOILING POINT
2607 °C

3

DENSITY
13.67 g/cm³

94

プルトニウム Plutonium

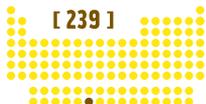
Pu

Actinide
Radioactive
solid
man-made



铀

ATOMIC ENERGY FOR
WEAPONS AND POWER



7

MELTING POINT
641 °C

BOILING POINT
3232 °C

3

DENSITY (25°C)
19.84 g/cm³

96

キュリウム Curium

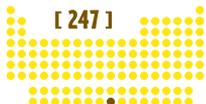
Cm

Actinide
Radioactive
solid
man-made



鍋

NAMED AFTER PIERRE
AND MARIE CURIE



7

MELTING POINT
1337 °C

BOILING POINT
3110 °C

3

DENSITY
13.3 g/cm³

97

バークリウム

Berkelium

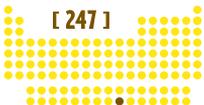
Bk

Actinide
Radioactive
Solid
man-made

鍍



MADE IN THE UNIVERSITY OF CALIFORNIA, BERKELEY



7

MELTING POINT
1047 °C

BOILING POINT
--- °C

3

DENSITY
14.79 g/cm³

99

アインスタイニウム

Einsteinium

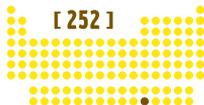
Es

Actinide
Radioactive
Solid
man-made

鍍



FOUND DURING THE HYDROGEN BOMB EXPERIMENTS



7

MELTING POINT
860 °C

BOILING POINT
--- °C

3

DENSITY
--- g/cm³

98

カリホルニウム

Californium

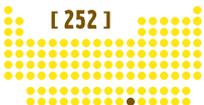
Cf

Actinide
Radioactive
Solid
man-made

鋼



IT'S SUPER EXPENSIVE!
ONE GRAM COSTS
A BILLION DOLLARS?!



7

MELTING POINT
897 °C

BOILING POINT
--- °C

3

DENSITY
15.1 g/cm³

100

フェルミウム

Fermium

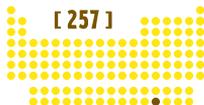
Fm

Actinide
Radioactive
Solid
man-made

鍍



NAMED AFTER ENRICO FERMI,
WHO DEVELOPED THE FIRST
ATOMIC REACTOR



7

MELTING POINT
--- °C

BOILING POINT
--- °C

3

DENSITY
--- g/cm³

101

メンデレビウム
Mendelevium

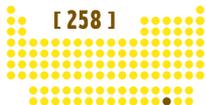
Md

Actinide
Radioactive
Solid
Man-made



釷

NAMED AFTER THE FATHER
OF THE TABLE OF THE
ELEMENTS, MENDELEEV



7

MELTING POINT

--- ℃

BOILING POINT

--- ℃

3

DENSITY

--- g/cm³

103

ローレンシウム
Lawrencium

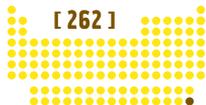
Lr

Actinide
Radioactive
Solid
Man-made



鏷

NAMED AFTER ERNEST
LAWRENCE, THE PHYSICIST



7

MELTING POINT

--- ℃

BOILING POINT

--- ℃

3

DENSITY

--- g/cm³

102

ノーベリウム
Nobelium

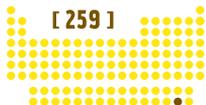
No

Actinide
Radioactive
Solid
Man-made



鏷

NAMED AFTER THE
HONORABLE ALFRED NOBEL



7

MELTING POINT

--- ℃

BOILING POINT

--- ℃

3

DENSITY

--- g/cm³

104

ラザホージウム
Rutherfordium

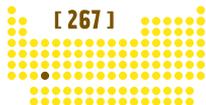
Rf

Transition
metal
Radioactive
Solid
Man-made



鏷

NAMED AFTER ERNEST
RUTHERFORD, WHO DISCOVERED
THE STRUCTURE OF THE ATOM



7

MELTING POINT

--- ℃

BOILING POINT

--- ℃

4

DENSITY

23 g/cm³

105

ドブニウム Dubnium

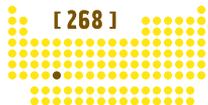
Db

Transition metal
Radioactive
solid
man-made

鉨



NAMED AFTER DUBNA, RUSSIA,
HOME OF THE JOINT INSTITUTE
FOR NUCLEAR RESEARCH



7	MELTING POINT	---	℃
5	BOILING POINT	---	℃
	DENSITY	29	g/cm ³

107

ボーリウム Bohrium

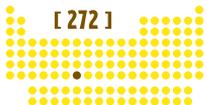
Bh

Transition metal
Radioactive
solid
man-made

鉈



NAMED AFTER THE DANISH
PHYSICIST NIELS BOHR



7	MELTING POINT	---	℃
7	BOILING POINT	---	℃
	DENSITY	37	g/cm ³

106

シーボーギウム Seaborgium

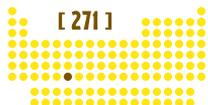
Sg

Transition metal
Radioactive
solid
man-made

鍮



NAMED AFTER
GLENN SEABORG, WHO
DISCOVERED TEN ELEMENTS



7	MELTING POINT	---	℃
6	BOILING POINT	---	℃
	DENSITY	35	g/cm ³

108

ハッシウム Hassium

Hs

Transition metal
Radioactive
solid
man-made

鏷



NAMED AFTER ITS
PLACE OF DISCOVERY,
HESSE IN GERMANY



7	MELTING POINT	---	℃
8	BOILING POINT	---	℃
	DENSITY	41	g/cm ³

109

マイトネリウム
Meitnerium

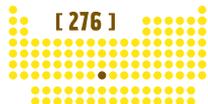
Mt

Transition metal
Radioactive
solid
man-made

𨭉



NAMED AFTER THE FEMALE
AUSTRIAN PHYSICIST,
LISE MEITNER



7

MELTING POINT

--- °C

BOILING POINT

--- °C

9

DENSITY

--- g/cm³

111

レントゲニウム
Roentgenium

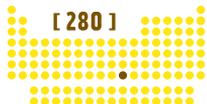
Rg

Transition metal
Radioactive
solid
man-made

𨭉



NAMED AFTER THE PHYSICIST
WHO DISCOVERED THE X-RAY,
WILHELM RÖNTGEN



7

MELTING POINT

--- °C

BOILING POINT

--- °C

11

DENSITY

--- g/cm³

110

ダムスタチウム
Darmstadtium

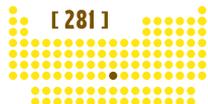
Ds

Transition metal
Radioactive
solid
man-made

𨭉



NAMED AFTER ITS PLACE OF
DISCOVERY, DARMSTADT



7

MELTING POINT

--- °C

BOILING POINT

--- °C

10

DENSITY

--- g/cm³

112

コペルニシウム
Copernicium

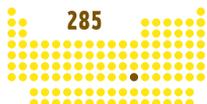
Cn

Radioactive
man-made

𨭉



NAMED AFTER COPERNICUS,
THE ASTRONOMER WHO
PREACHED ABOUT THE
HELIOCENTRIC THEORY



7

MELTING POINT

--- °C

BOILING POINT

--- °C

12

DENSITY

--- g/cm³

113	ウンウトリウム Ununtrium
Uut	284 
SCIENTIFIC USES DISCOVERY YEAR: 2004	7 13

116	リバモリウム Livermorium
Lv	radioactive man-made 293 
SCIENTIFIC USES DISCOVERY YEAR: 2000	7 16

114	フレロビウム Flerovium
Fl	radioactive man-made 289 
SCIENTIFIC USES DISCOVERY YEAR: 1998	7 14

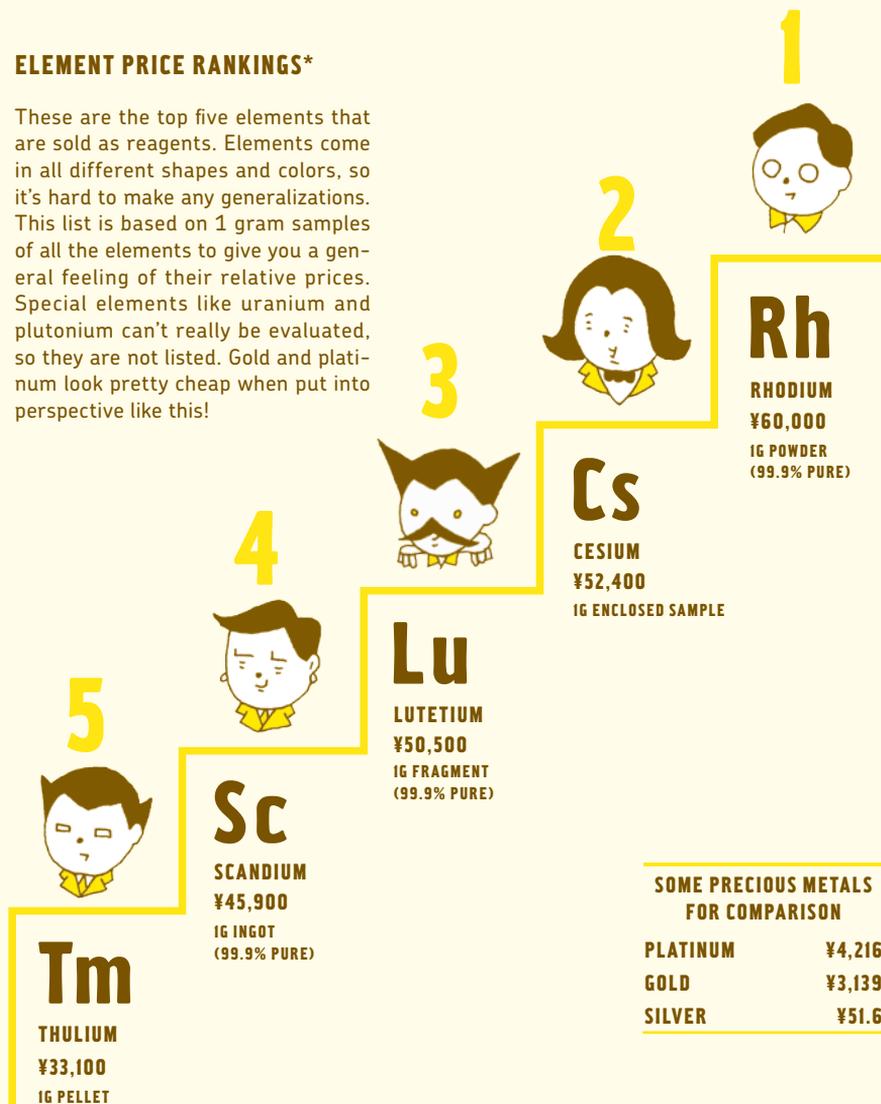
117	ウンウンセプチウム Ununseptium
Uus	--- 
SCIENTIFIC USES DISCOVERY YEAR: 2010	7 17

115	ウンウンペンチウム Ununpentium
Uup	288 
SCIENTIFIC USES DISCOVERY YEAR: 2003	7 15

118	ウンウンオクチウム Ununoctium
Uuo	294 
SCIENTIFIC USES DISCOVERY YEAR: 2003	7 18

ELEMENT PRICE RANKINGS*

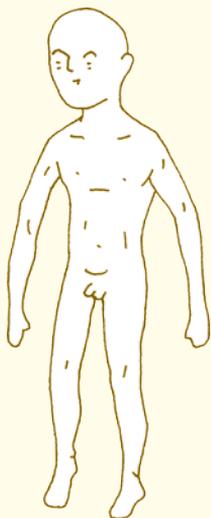
These are the top five elements that are sold as reagents. Elements come in all different shapes and colors, so it's hard to make any generalizations. This list is based on 1 gram samples of all the elements to give you a general feeling of their relative prices. Special elements like uranium and plutonium can't really be evaluated, so they are not listed. Gold and platinum look pretty cheap when put into perspective like this!



* There are roughly 100 Japanese yen to 1 US dollar.

THE COST OF ONE HUMAN BEING

How much does a human cost? I tried to calculate the price using common materials that anyone can buy and included most of the elements in the human body. If we assume that the person weighs around 60 kg (132 lbs), the body's worth roughly ¥13,000. I guess it's up to each person to decide how much tax goes on top of that...



+

≈

ZINC	¥0.5	0.12 G EQUIVALENT OF ZINC FOR EXPERIMENTAL USE
IRON	¥14	3 G EQUIVALENT IN IRON NAILS
SODIUM & CHLORINE	¥20	180 G EQUIVALENT IN TABLE SALT
SULFUR	¥288	120 G EQUIVALENT IN SULFUR FOR EXPERIMENTAL USE
PHOSPHORUS	¥300	600 G EQUIVALENT IN PHOSPHORUS-BASED FERTILIZER
POTASSIUM	¥605	240 G EQUIVALENT IN POTASSIUM-BASED FERTILIZER
NITROGEN	¥774	1.8 KG EQUIVALENT IN NITROGEN-BASED FERTILIZER
CARBON	¥896	10.8 KG EQUIVALENT IN BARBECUE COAL
CALCIUM	¥1,766	0.9 KG EQUIVALENT IN CALCIUM CARBONATE FOR EXPERIMENTAL USE
OXYGEN & HYDROGEN	¥3,980	45 KG EQUIVALENT IN WATER
MAGNESIUM	¥4,200	30 G EQUIVALENT IN MAGNESIUM FOR EXPERIMENTAL USE
OTHERS		

¥13,000

ELEMENT FRIENDS

Among the 118 elements, certain groups of elements have similar properties, and some of them even reinforce each other's reactions. There are elements who play well with others and others who just want to pick a fight...



Au Ag Cu

THE THREE SAGES OF WEALTH AND PROSPERITY

Gold, silver, and copper are all abundant, easy to work with, and corrosion resistant, which makes them an exceptionally accomplished team of metals. This is why they have been used since ancient times as currency, raw materials, and prized possessions. The well-known set of Olympic medals is just one example of many.

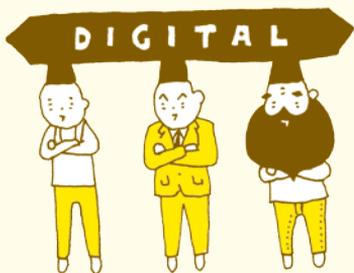


Na K Rb Cs

THE FOUR EXPLOSIVE ALKALI EMPERORS

These four elements may seem like a peaceful bunch, but if you get them wet, you'll see just how explosive their tempers can be! Their pure forms must be kept submerged in oil to prevent the violent reaction caused by contact with water. From least explosive to most explosive they are Sodium, Potassium, Rubidium, and Cesium.



**Si****Ge****Sn****THE DIGITAL
SEMICONDUCTOR TRIO**

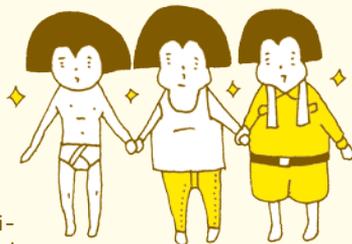
Silicon, germanium, and tin are the three main elements used in semiconductor construction. They are the elite few that helped Japan become one of the leading countries in electronics. It is thanks to them that we have access to computers and other digital devices today.

Ca**Sr****Ba****THE CASBAH BROTHERS**

Sometimes elements with very similar properties and very regularly spaced atomic weights form groups of three in the table of elements. These groups are called “triads.” Calcium, strontium, and barium form one of these groups, and since their starting letters are *Ca*, *S*, and *Ba*, I thought “the Casbah brothers” might be a good family name for them.

**Nd****Sm****THE STRONGEST MAGNET COMBO
IN THE WORLD**

Neodymium and samarium are engaged in an eternal struggle for the title of “world’s best magnet.” That honor currently goes to neodymium, but samarium magnets are both more heat resistant and more rugged, which makes them the better choice in many applications.



TROUBLESOME ELEMENTS

Elements that aren't that dangerous by themselves can gain unimaginable destructive power when paired with a few others. I thought we could have a look at a few of the groups that have been stirring up trouble in the world these last few decades.



As_2O_3 (As_4O_6)

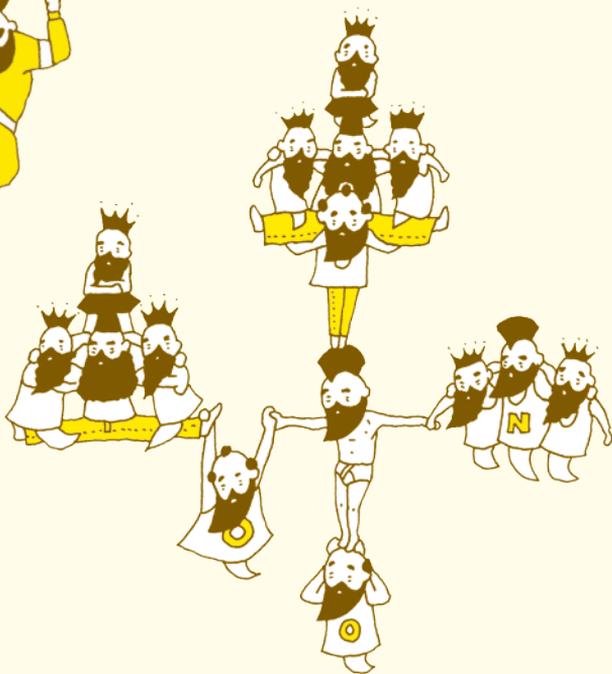
ARSENIC TRIOXIDE

Arsenic trioxide was used in the assassination of Napoleon and in the infamous Wakayama curry poisoning in the summer of 1998.

$C_2H_8NO_2PS$

METHAMIDOPHOS

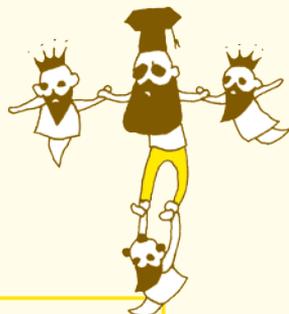
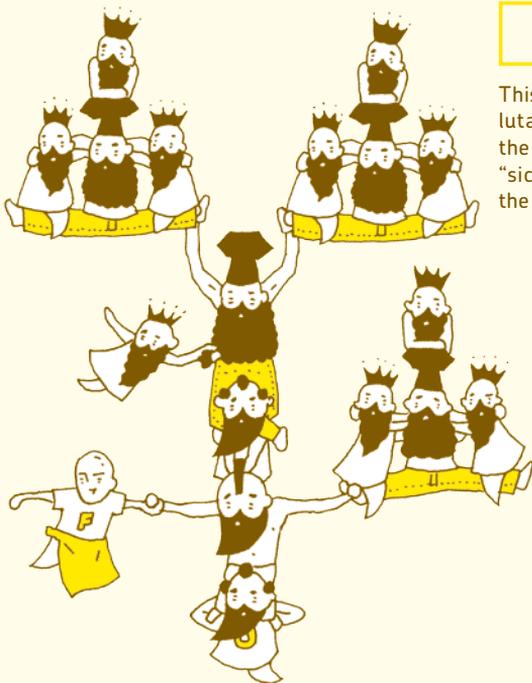
Methamidophos became famous in Japan when trace amounts of the poison were found in foodstuffs imported from China. It is made up of a multitude of elements.



C₄H₁₀O₂FP

SARIN

Even though sarin is made up of some very familiar elements, it is an extremely potent nerve gas.



CH₂O

FORMALDEHYDE

This harmful indoor air pollutant was named as one of the elements responsible for “sick building syndrome” in the 1980s.



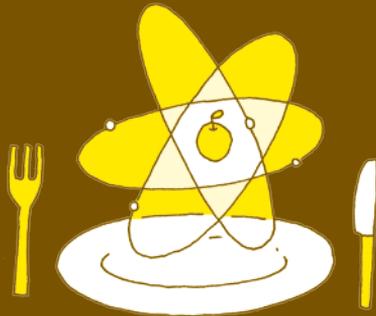
KCN

POTASSIUM CYANIDE

The classic poison used throughout history has a surprisingly simple chemical formula.



4



HOW TO EAT THE ELEMENTS

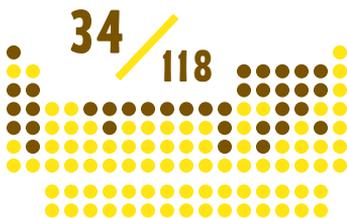
元素の食べ方

Our bodies are also made of elements—about 34 different elements, actually. That means that over one third of all the elements we’ve looked at so far are actually a part of us. It’s easy to think that elements exist only in the outside world, but...

WE’RE ALL ELEMENT TREASURE HOUSES.

And among them are lots of elements that you might have thought you’d never have anything to do with, like strontium or molybdenum. It might surprise you to know that arsenic is one of them, too. Arsenic, which is almost synonymous with poison, actually exists naturally within us. This is also true for other unfamiliar elements like cadmium, beryllium, and radium. They’re all a part of our bodies.

But of course elements are not created inside our bodies. They are all there because we’ve eaten them at some point. Before that, they were part of some other entity.



● = ELEMENTS IN OUR BODIES

THE ELEMENTS
INSIDE OUR
BODIES



H

HYDROGEN



B

BORON



C

CARBON



N

NITROGEN



O

OXYGEN



F

FLUORINE



Na

SODIUM



Mg

MAGNESIUM



Al

ALUMINUM



Si

SILICON



P

PHOSPHORUS



S

SULFUR



Cl

CHLORINE



K

POTASSIUM



Ca

CALCIUM



V

VANADIUM



Cr

CHROMIUM



Mn

MANGANESE



Fe

IRON



Co

COBALT



Ni

NICKEL



Cu

COPPER



Zn

ZINC



As

ARSENIC



Se

SELENIUM



Rb

RUBIDIUM



Sr

STRONTIUM



Mo

MOLYBDENUM



Cd

CADMIUM



Sn

TIN



I

IODINE



Ba

BARIUM



Hg

MERCURY



Pb

LEAD

The average human is made up of about 65% oxygen, 18% carbon, and 10% hydrogen.

WAIT A SECOND! THAT'S ALMOST 100%!

In reality, about 28 of those 34 elements don't even amount to 1% of our total mass. But just because these elements appear in tiny amounts doesn't mean they're not important—quite the opposite! Even if only a tenth of a percent of the elements in our bodies were to go missing, we'd be dead. These low-volume but important elements are called *trace elements*, and most of them are metals. The most important of these are called...

MINERALS.

Minerals are absolutely necessary to all living beings, including humans.

ABUNDANT ELEMENTS

★ PHOSPHORUS

1.0%

★ CALCIUM

1.5%

NITROGEN

3.0%

HYDROGEN

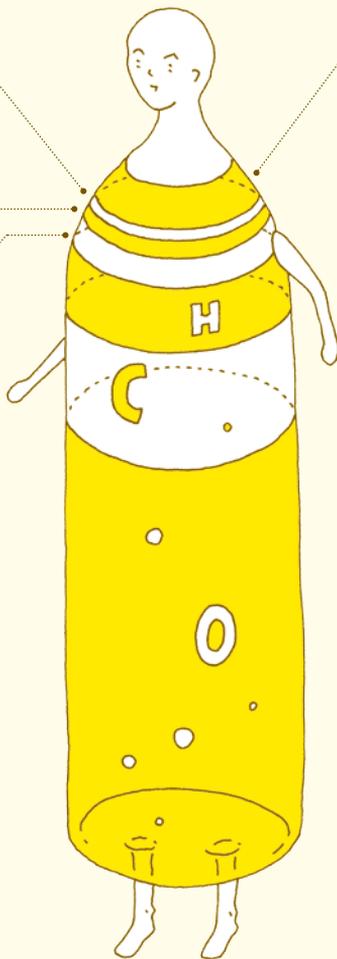
10%

CARBON

18%

OXYGEN

65%



OTHERS

1.5%

RARE

- ★ SULFUR
- ★ POTASSIUM
- ★ SODIUM
- ★ CHLORINE
- ★ MAGNESIUM

VERY RARE

- ★ IRON
- ★ FLUORINE
- SILICON
- ★ ZINC
- STRONTIUM
- RUBIDIUM
- LEAD
- ★ MANGANESE
- ★ COPPER

ULTRA RARE

- ALUMINUM
- CADMIUM
- TIN
- BARIUM
- MERCURY
- ★ SELENIUM
- ★ IODINE
- ★ MOLYBDENUM
- NICKEL
- BORON
- ★ CHROMIUM
- ARSENIC
- ★ COBALT
- VANADIUM

★ = MINERALS

Right now, there are around 17 recognized dietary minerals.* They are the starting point for many compounds, and they help control how other elements react with each other.

THEY ARE LIKE THE PLAYMAKERS OF OUR BODIES.

If the body were an orchestra, the minerals would be its conductor. If it were an airport, the minerals would be its control tower. If a company, its director. That is what minerals do. If we run low on iron, we get anemic, and if we don't get enough calcium, we get irritated. Our bodies cannot function without proper playmakers, just like a good soccer team.

BUT MORE DOESN'T MEAN BETTER.

It's best to have just a few leaders. Nothing good ever comes from having too many. I will introduce all 17 dietary minerals in this chapter, including how they help our bodies, in which types of food they can be found, and what happens if we take in too much or too little.

* There's still some disagreement about which of these are essential to living organisms—some scientists say 13, some say 20 or more. Note that these dietary minerals should not be confused with “minerals” in the general sense, of which there are over 4,000!



Minerals are conductors.

Na

CAN BE FOUND IN



Pickles



Miso



Dried Foods



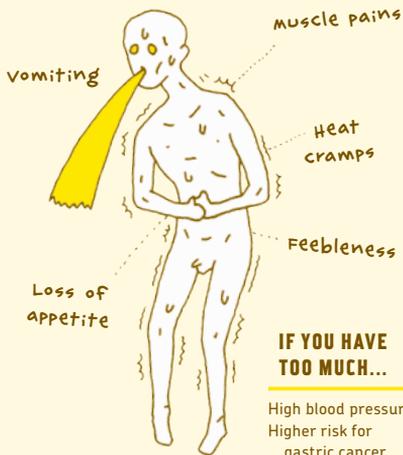
Soy sauce



Sauces

SODIUM

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

High blood pressure
Higher risk for gastric cancer
Dehydration
High body temperature

**THE MOST IMPORTANT
LIFESAVER MINERAL
OF THEM ALL**

Most of our sodium intake is from table salt (sodium chloride). Many people have cut down on salt in their diet because it can cause problems. But if you ever find yourself sweating a lot or sick with diarrhea, consider taking supplemental sodium because of all the liquid loss, or you might find yourself with a deficiency.

**RECOMMENDED
DAILY INTAKE
(AVERAGE)**

600 mg

Mg

CAN BE FOUND IN



Toasted nori



spinach



Bananas



kelp



soybeans



Fish



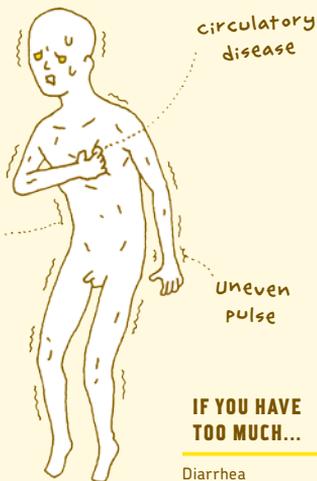
seaweed



sesame

MAGNESIUM

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

Diarrhea
Low blood pressure
Abdominal cramping

BUILDING OUR BODIES! THE MEATY ELEMENT

Magnesium is found in our bones, where it keeps them strong and helps promote growth, and in our brains, where it helps maintain the thyroid gland. It also helps activate all types of enzymes. Chronic alcoholics should take note: When lots of alcohol leaves our bodies, it takes significant amounts of magnesium with it.

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
320 – 370 mg

WOMEN
260 – 290 mg

K

CAN BE FOUND IN



Persimmons



Bananas



sweet potatoes



Spinach



Tomatoes



soybeans



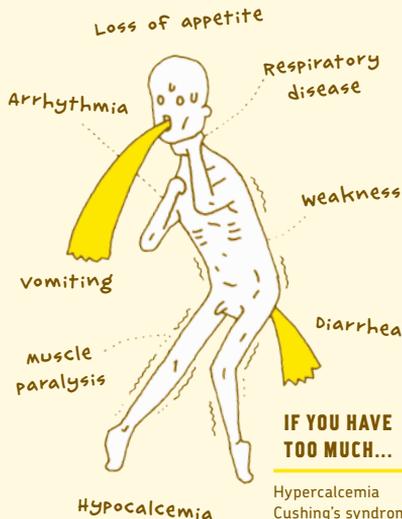
watermelons



sardines

POTASSIUM

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

Hypercalcemia
Cushing's syndrome
Uremia
Urinary occlusion

THE MEGA MULTITASKER

Potassium is always on the move. Be it composing proteins, managing the liquid level between cells, or just taking care of one of the many signaling duties that must be performed, potassium is on the job. Any extra potassium is dealt with by the kidneys, so if they fail, taking too much becomes a definite health risk.

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
2500 mg

WOMEN
2000 mg

Ca

CAN BE FOUND IN



Dairy products



Dried radish



dried young sardines



seaweeds



Dried shrimp



sardines



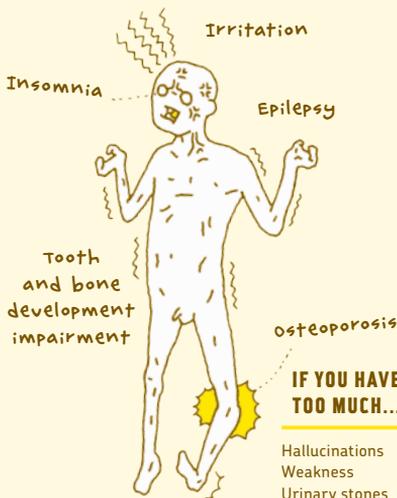
Tofu



spinach

CALCIUM

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

Hallucinations
Weakness
Urinary stones
Difficulty absorbing other minerals
Hypercalcemia

THE STEADY MAINSTAY WHO KNOWS HOW TO MAKE STRONG BONES

Most people know that calcium is essential for tooth and bone growth, but its usefulness doesn't stop there, as it has a multitude of other functions. It often works with magnesium, so taking both elements at the same time usually makes them work more efficiently. Vitamin D makes digesting calcium easier.

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
650 – 800 mg

WOMEN
600 – 650 mg

P

CAN BE FOUND IN



Dairy products



seaweeds



Grains



Fruits



Fish and shellfish



Beans



meats



NUTS

PHOSPHORUS

IF YOU DON'T HAVE ENOUGH...

Decreased muscle strength

Aparathyroidism



IF YOU HAVE TOO MUCH...

Calcium absorption difficulties
Hyperparathyroidism
Decreased kidney function

BUILDING OUR DNA! THE INTELLECTUAL ELEMENT

Phosphorus, famous as the ignition agent of matches, not only is responsible for the information in our DNA but is also a vital component in our cell membranes and neurons. It is also used as an additive in processed foods and as a preservative, so some people think we are taking in too much phosphorus these days.

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
1000 mg

WOMEN
900 mg

Zn

CAN BE FOUND IN



Almonds



Cashews



Oysters



Kouya
tofu



Cod roe



Liver



Saury



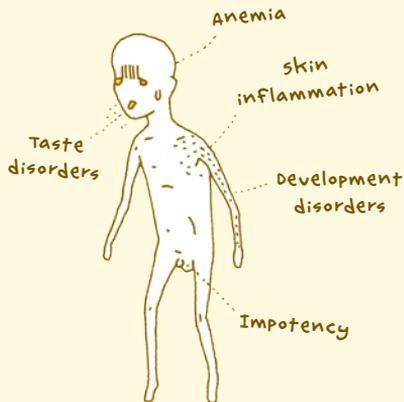
Scallops



Eel

ZINC

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

Gastrointestinal irritation, low blood pressure, uropenia, anemia, pancreatic disorders, increase of LDLs, decrease of HDLs, decrease of immune response, headaches, nausea, stomachache, diarrhea

THE LOVING MOTHER ELEMENT

Zinc is required for protein composition as well as correct propagation of gene information and gene expression. Suffering from a zinc deficiency during puberty might affect the development of secondary sex characteristics such as facial hair for men and breast size for women. So even teenagers should eat properly!

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
11–12 mg

WOMEN
9 mg

Cr

CAN BE FOUND IN



Black pepper



Whole grains



Brewer's yeast



Beans



Mushrooms



Liver



Shrimp

CHROMIUM

IF YOU DON'T HAVE ENOUGH...

corneal disease

Diabetes

High cholesterol

Arterial hardening

Glucose intolerance

IF YOU HAVE TOO MUCH...

Gastrointestinal disorders
Central nervous system disorders
Liver and kidney disease
Development disorders
Increased risk for lung cancer



THE GUARDIAN DEITY OF OUR BLOOD SUGAR LEVELS

Most of the chromium in our food is trivalent chromium, which is used in the metabolism of sugars, proteins, and cholesterol. Deficiencies might lead to diabetes or high cholesterol levels, but the amount you need is very small and can be found in basically all foods.

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
35 – 40 µg

WOMEN
25 – 30 µg

Se

CAN BE FOUND IN



Sesame seeds



Fish and shellfish



chocolate



Eggs



seaweeds



Beef



Liver



squid

SELENIUM

IF YOU DON'T HAVE ENOUGH...



Heart disease

Increased risk of lifestyle diseases such as cancer and Alzheimer's disease

IF YOU HAVE TOO MUCH...

Fatigue, nausea, stomachache, diarrhea, peripheral neuropathy, liver cirrhosis, rough skin, hair loss, gastrointestinal disorders, vomiting, nail disfigurement

THE YOUNG SUPPORTER, CHEERING LIFE ON

Working as an antioxidant and an immunity booster, selenium helps prevent lifestyle diseases. But having too much is highly toxic and can lead to nail disfigurement and hair loss. It works best when taken together with vitamin E, which can be found in most types of nuts.

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
30 µg

WOMEN
25 µg

Mo

CAN BE FOUND IN



Liver



Grains



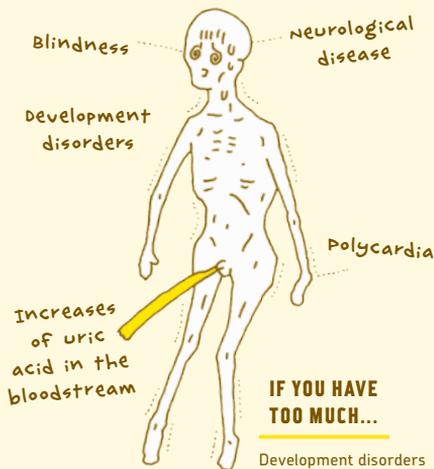
Beans



Dairy products

MOLYBDENUM

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

Development disorders
Neurological symptoms
Arthritis
Anemia

**SUPPORTING
OUR ENZYMES!
THE BODY'S
MAINTENANCE MAN**

In addition to assisting our enzymes, molybdenum also boosts the effect of iron in our system, which reduces the risk for anemia. We don't need a lot of it, and you should be able to get enough from almost any diet. Milk contains a lot of molybdenum; around 25–75 μg per liter!

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
25 – 30 μg

WOMEN
20 – 25 μg

Fe

CAN BE FOUND IN



soybeans



chicken



Liver



spinach



Eggs



sardines



Brown algae



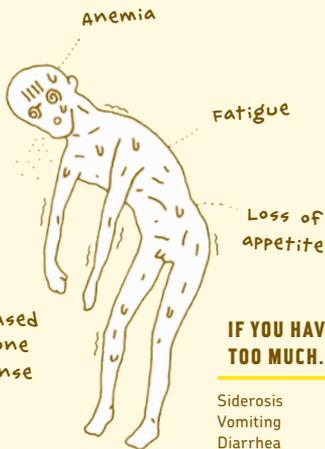
sesame seeds



Turtle blood

IRON

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

Siderosis
Vomiting
Diarrhea
Shock
GI disorders
(constipation, nausea)

THE LEADER OF THE MINERALS WHO KEEPS US HAPPY AND HEALTHY!

Even the ancient Greeks knew about the relationship between iron and our bodies. Almost 65% of all the iron we consume is used in blood production, so running short is a definite risk. Taking it with vitamin C makes it easier for us to absorb, but tea and coffee have the opposite effect because of something called *tannin*.

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
7.0 – 7.5 mg

WOMEN
6.0 – 11.0 mg

I

CAN BE FOUND IN



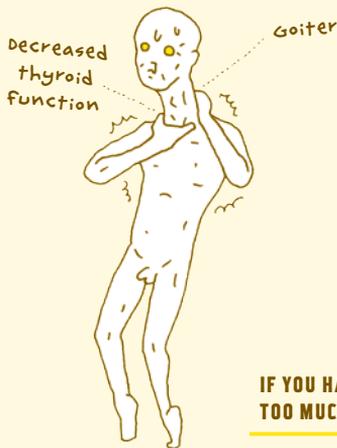
seaweeds



Fish and shellfish

IODINE

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

Goiter
Grave's disease
Hyperthyroidism

THE LIFE-FORCE SPOUTING POWER PUMP

A mineral that affects both body and mind, iodine is a vital component in the thyroid hormones that control metabolism and the autonomic nervous system. Since it's common in seafood, island nations like Japan have no problem with absorbing enough. Inland areas of America depend on adding iodine to table salt.

RECOMMENDED DAILY INTAKE (AVERAGE)

130 µg

Cu

CAN BE FOUND IN



Brewer's yeast



chocolate



shellfish



cow liver



mushrooms



crustaceans



Beans



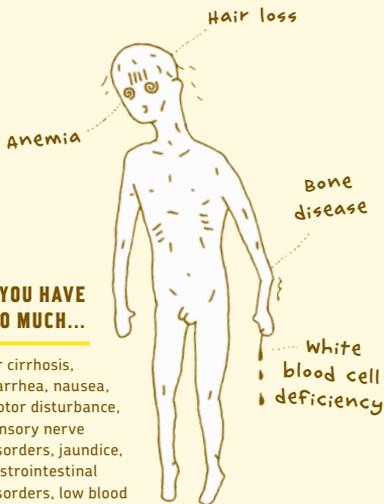
Fruits



squid and octopus

COPPER

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

Liver cirrhosis, diarrhea, nausea, motor disturbance, sensory nerve disorders, jaundice, gastrointestinal disorders, low blood pressure, hematuria, anuria

STOPPING HEART ATTACKS! THE KEY TO A LONG LIFE

People don't really think of it as a mineral, but there are over 100 mg of copper in an adult body, residing mainly in the blood, brain, liver, and kidneys. It also has a proven preventive effect against heart attacks and arterial sclerosis, so middle-aged and elderly people would do well to eat lots of fish!

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
0.8 – 0.9 mg

WOMEN
0.7 mg

Mn

CAN BE FOUND IN



Green tea



Beef



Oysters



Seaweeds



Beans



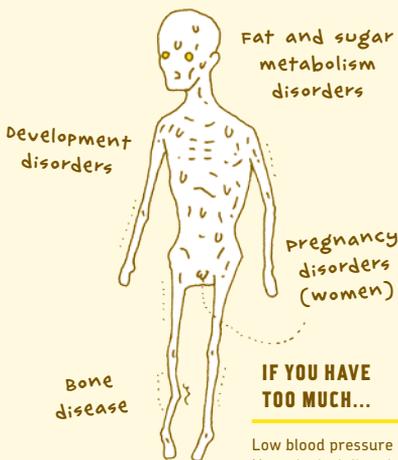
powdered green tea



clams

MANGANESE

IF YOU DON'T HAVE ENOUGH...



IF YOU HAVE TOO MUCH...

Low blood pressure
Neurological disorders
Headaches
Motor function disorders
Language disorders
Parkinson's-like diseases

THE SUPPORTING ELEMENT THAT NAILS THE IMPORTANT PARTS

A 70 kg adult contains about 12 mg of manganese. It is extra important to pregnant women and affects our motor functions. Experiments with rats have shown that manganese deficiencies can lead to smaller testicles in males. But you don't have to worry about that as long as you have a relatively normal diet.

RECOMMENDED DAILY INTAKE (AVERAGE)

MEN
4.0 mg

WOMEN
3.5 mg

S

硫黄
Sulfur



Eggs



meats

Sulfur is a component of the amino acids that make up the proteins in our bodies and keep us healthy by maintaining our skin, nails, and hair. Deficiencies can lead to skin inflammation and diminished metabolism. It can be found in eggs, meat, and fish.

**RECOMMENDED
DAILY INTAKE
(AVERAGE)**

MEN
10 – 12 mg

WOMEN
9 – 10 mg

Cl

塩素
Chlorine



soy
sauce



Miso

Chlorine is very important to the digestive system, as it is one of the main components of the hydrochloric acid (gastric acid) secreted into the stomach. As it can be found in table salt, deficiencies should never become a problem. Excess chlorine is excreted through both sweating and urination, so no worries there either.

**RECOMMENDED
DAILY INTAKE
(AVERAGE)**

**NOT
NOTEWORTHY**

F

フッ素
Fluorine



green
tea



Fish and
shellfish

Fluorine keeps our bones and teeth strong. Since sodium fluoride also has preventive effects on cavities, small amounts are put into the tap water in some areas. Japanese people never have to worry about running low on fluorine since large quantities can be found in both seafood and green tea leaves.

**RECOMMENDED
DAILY INTAKE
(AVERAGE)**

**NOT
NOTEWORTHY**

Co

コバルト
Cobalt



meats



oysters

You shouldn't have to worry about cobalt deficiencies if you make sure to eat a lot of seafood and meat proteins, as they contain vitamin B12, which in turn contains the mineral. Not having enough cobalt can lead to anemia, no matter how much iron you take in. It might not be a very versatile element, but it is important nonetheless.

**RECOMMENDED
DAILY INTAKE
(AVERAGE)**

**NOT
NOTEWORTHY**

朝ごはんの元素たち

ELEMENTS IN BREAKFAST

*I've listed all elements except C, N, H, and O since they are in all items.

PICKLED RADISH

- K
- Cl
- Na
- Mg

SOY SAUCE

- Cl
- Na
- K

TANGERINE

- Cu
- Mg
- K
- Ca
- P

GREEN TEA

- Se
- Mn
- F
- P

SARDINE

- Ca
- K
- P
- Co
- Fe
- Mg
- Se
- I
- Cr
- S
- Mn
- Zn
- S
- F
- Mo
- Na

RICE

- Ca
- Fe
- Mg
- K
- Zn
- P
- Mo
- Mn

MISO SOUP WITH SEAWEED AND TOFU

SEAWEED

- Na
- Mg
- Ca
- P
- Fe
- Se
- I
- Mn
- F

TOFU

- Mg
- Na
- Ca
- P
- Mo
- Mn
- Fe
- Zn

MISO

- K
- Na
- Cl
- Mg
- P
- Cr
- Fe
- Zn

NORI

- Mg
- I
- Ca
- P
- Se
- Mn
- Na
- Co
- Zn

Fish is better than meat.

There are lots of minerals in a Japanese breakfast.

Even more minerals if you choose brown rice!

和食の朝ごはん

JAPANESE BREAKFAST

Even more minerals if it contains bean sprouts!



BREAD

- P K Fe
- Na Cl Ca
- Mn

SALAD

- Ca K Fe
- Zn Mg Mn
- P

FRUIT YOGURT

YOGURT

- Ca Mo K Mg
- P I Co Na

FRUITS

- K Mg Cu Zn
- P

BUTTER

- Ca Mg Na
- K Co P
- Se Cu

CORN SOUP

- Ca Fe K
- Na P Zn
- Cu

COFFEE

- K

sprinkle a little salt on your eggs for more iodine.



BACON AND EGGS

BACON

- P Cl Mg
- Na K S

EGGS

- Se Fe Ca P Cr
- S Zn Co K

BLACK PEPPER

- Cr K

Eggs also contain a lot of minerals.



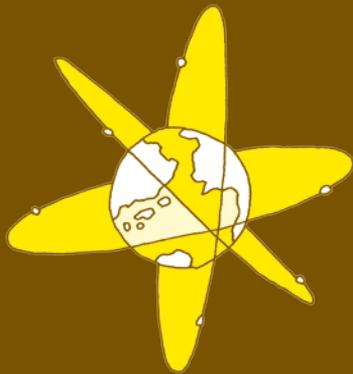
洋食の朝ごはん

EUROPEAN AND AMERICAN BREAKFAST



He's just
overworked.

5



THE ELEMENTS CRISIS

元素危機

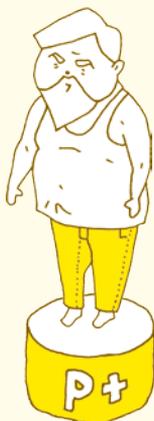
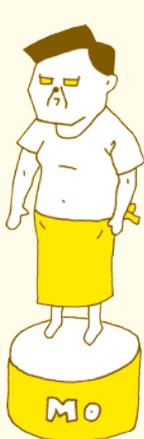
Some of the elements we've looked at so far, like germanium, were very popular a few years back but aren't really used any more. Other elements like indium only recently came into the spotlight.

SOME ELEMENTS ARE SO POPULAR, IT'S BECOMING A PROBLEM.

Long ago, batteries were made using nickel. Because of this, the price of nickel skyrocketed, forcing us to come up with the lithium battery as a cheaper replacement. Indium, used in LCD displays, is also getting more expensive by the year. Scarce elements like indium and elements that are generally very hard to process or extract are called *rare metals*.

ALMOST ALL RARE METALS IN JAPAN ARE IMPORTED TODAY.

Of course, Japan didn't really have any natural rare metal resources to begin with. Since Japan is importing almost its entire demand for rare metals, it would be extremely bad if that stream of raw materials were ever to stop.



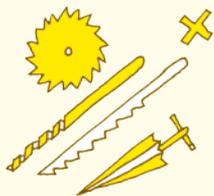
The rarest metals

Tungsten is required to make the tools we need to build things. Nickel and molybdenum imports let us create stainless steel products. And gallium and its related metals are the basis for our semiconductors. No semiconductors means no computers or mobile phones. These few elements carry Japan's economy on their shoulders.

BUT THE RISK OF AN ELEMENT CRISIS IS VERY REAL.

The popularity of some metals has driven their price up to the point that it's hard to acquire them at all. This is true not only for Japan but for the entire world. This makes the element crisis at least as serious as the impending oil crisis, and some countries have already begun stockpiling hard-to-find elements while they promote research for potential replacements.

But it might not be enough. We, as different countries and cultures, must learn to work together to solve the crisis.



We won't be able to make strong tools without tungsten.

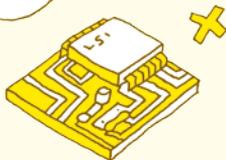


We can't make anything!

The manufacturing industry comes to a stop.



It's hopeless.



We can't make semiconductors when elements like gallium run out.



This also means no more computers and other high-tech equipment.



LCD TVs require indium.



Stainless steel is made of molybdenum and nickel.



And batteries are made with lithium.



I can't imagine a world without stainless steel.

We are now able to perform advanced recycling of home electronics and even mobile phones. It's not just about being kind to the environment, it's also about reclaiming precious rare metals from our garbage. In some cases the element could become unrecoverable if not processed correctly.

WE CANNOT MAKE ELEMENTS.

Why don't we just make elements if we need them so badly? Just put two hydrogen atoms together and you've got helium! The protons and electrons are all there, so how hard can it be?

IF WE COULD CREATE THEM LIKE THAT, THEY WOULDN'T BE ELEMENTS.

An atomic reaction or an incredible amount of energy is required to reshape an atomic nucleus. But inducing atomic reactions produces radioactive materials, which emit dangerous radioactive rays. The elements are called elements because they are hard to create and alter.



Lutetium,
please.

I'll go
put some
together.

wouldn't it be great
if this were real?

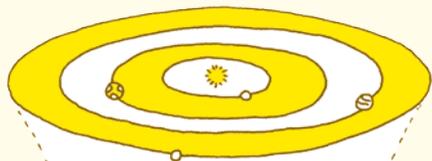
Our current way of life is supported by our use and knowledge of elements. It might not be apparent, but elements are responsible for the most basic parts of our modern world.

IN THE FUTURE, EVERYONE WILL BE A SCIENTIST.

The concept of the “low-carbon economy” has become more popular lately. Maybe we need to start examining our environmental problems at the element level as well. The greenhouse gas problem, for example, is aggravated by us humans releasing underground carbon dioxide into the atmosphere. The element crisis is of course another problem, and I’m hoping that you will become more aware of your rare metal usage after getting to know these elements a little better.

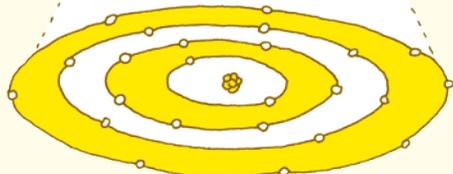
If we could get everyone to take an interest in the elements that make up our world and apply that knowledge in their daily lives, this looming crisis may never come to pass. I would be honored if you decided to adopt a more rare metal-aware lifestyle after reading this book.

UNIVERSE



OUR

LIFE



ELEMENT

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AFTERWORD

I imagine many people remember which element they first heard about. Mine was uranium. I was still in primary school when I saw the movie *Barefoot Gen* with my mother at the local community center. As some of you may know, the movie is about the bombing of Hiroshima during World War II. I still remember the intensity of the movie, and by the end of the show, it had rendered my young self completely speechless. The following weeks I had trouble sleeping, and the scene where the bomb explodes haunted me day and night. I convinced myself that I had to learn more about the bomb, not because I had some passing interest in it, but because I felt that I would never be able to let it go if I didn't. I was completely terrified. It was then that I first learned of the elements uranium and plutonium and of the world of neutrons, protons, and electrons. I recall how calming it was to read about the bomb and how it worked.

When I was contacted by Fumiko Kakoi of Kagaku Doujin to make a book about the periodic table, I didn't think much of the idea at first. I didn't really know much about the elements, even after my illuminating (and traumatic) experience with *Barefoot Gen* as a child. I wasn't sure how to proceed but finally decided to meet with Professor Kouhei Tamao of the Institute of Physical and Chemical Research and Professor Hiromu Sakurai of Kyoto Pharmaceutical University. They taught me about the impending element crisis and about the importance of the metals present in our bodies. It was a truly eye-opening experience to hear about the intricate bond that our bodies share with the elements. Everything I learned there and from then on finally coalesced into the book you're reading right now. I would like nothing more than to let my old self, the one who didn't care about the elements, read it, and I hope that it can be of help to anyone else who might want to take a gander.

I didn't complete this book by myself—far from it. My little sister Makiko Kajitani, who also happens to be a writer, helped me so much in so many ways that it might have been more fair to list her as a co-author. I am also very grateful to Takahito Terashima, whom I sadly never met, who helped me greatly in editing the book. And my companion for two years now, Kakoi-san of Kagaku Doujin, has helped me with every aspect of the book, from research and gathering materials to proofreading. Words cannot adequately describe the gratitude I feel toward you all.

Thank you so much.

Bunpei Yorifuji

ABOUT THE AUTHOR

Born in 1973 in Nagano, Japan, Bunpei Yorifuji is a Musashino Art University dropout. His other books include *The Catalog of Death* (*Shi ni Katarogu*) and *The Scale of Mind* (*Suuji no Monosashi*). He has also co-authored *Uncocoro* and *The Earthquake Checklist* (*Jishin Itsumonoto*), among others. Find out more about Bunpei and his works at <http://bunpei.com/>.

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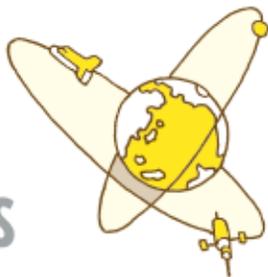
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UPDATES

Visit <http://nostarch.com/wle> for updates, errata, and other information.



GET TO KNOW THE ELEMENTS



From the brilliant mind of Japanese artist Bunpei Yorifuji comes *Wonderful Life with the Elements*, an illustrated guide to the periodic table that gives chemistry a friendly face.

In this *super* periodic table, every element is a unique character whose properties are represented visually: heavy elements are fat, man-made elements are robots, and noble gases sport impressive afros. Every detail is significant, from the length of an element's beard to the clothes on its back. You'll also learn about each element's discovery, its common uses, and other vital stats like whether it floats—or explodes—in water.

Why bother trudging through a traditional periodic table? In this periodic paradise, the elements are people too. And once you've met them, you'll never forget them.



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