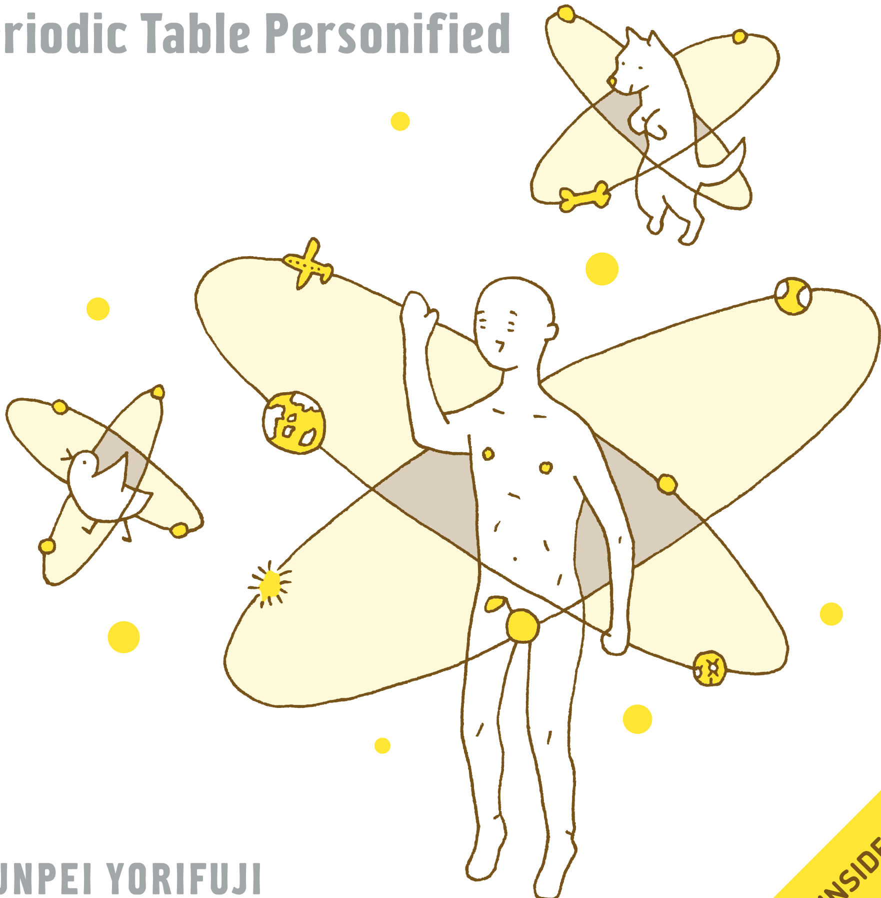
Wonderful Life with the Elements

The Periodic Table Personified

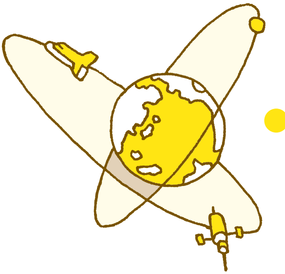


BUNPEI YORIFUJI

POSTER INSIDE!

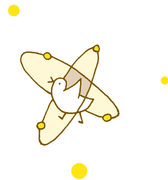
Wonderful Life with the Elements

The Periodic Table Personified



by Bunpei Yorifuji

no starch press



Printed in China

First printing

15 14 13 12 1 2 3 4 5 6 7 8 9

ISBN-10: 1-59327-423-8
ISBN-13: 978-1-59327-423-8

For information on book distributors or translations, please contact No Starch Press, Inc.:

No Starch Press, Inc.
38 Ringold Street, San Francisco, CA 94103
phone: 415.863.9900; fax: 415.863.9950; info@nostarch.com; http://www.nostarch.com/

Library of Congress Cataloging-in-Publication Data
A catalog record of this book is available from the Library of Congress.

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.

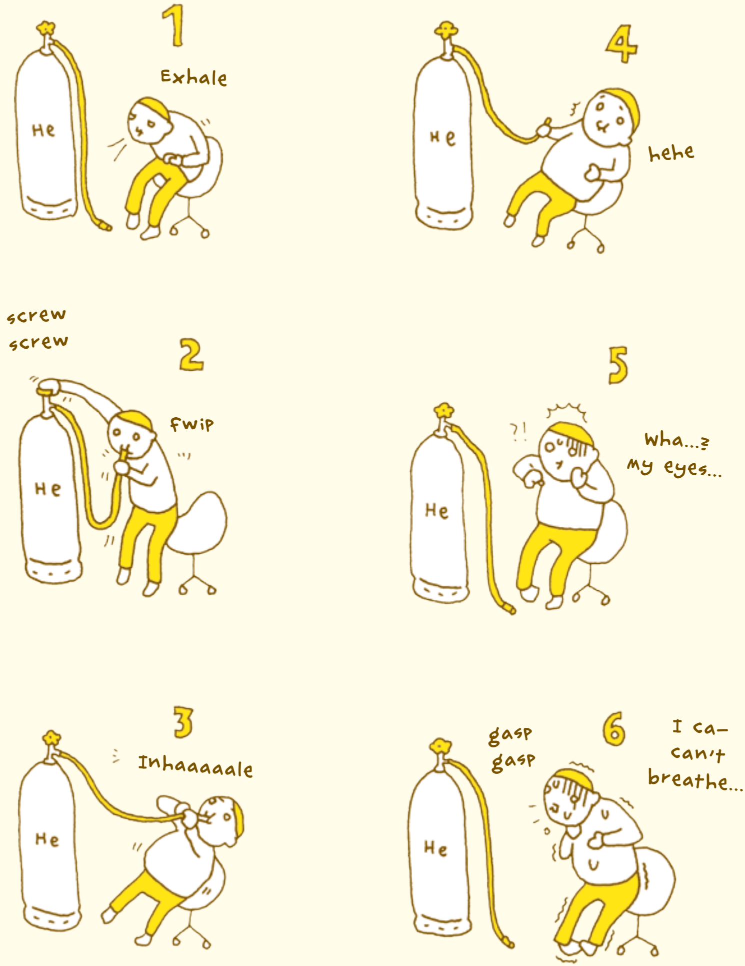
"BUT I MIGHT BE ABLE TO PRODUCE SOME REALLY FUNKY NOISES WITH THESE."

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.

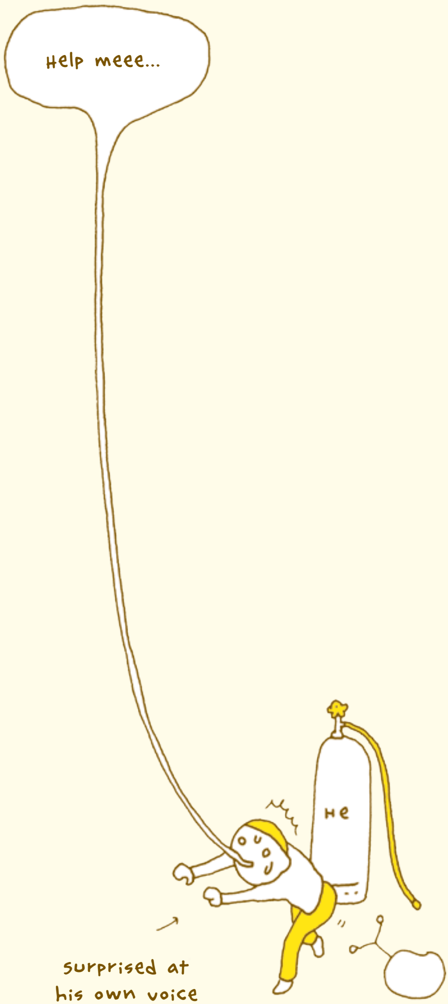

1
Exhale
He
2
screw
screw
fwip
He
3
Inhaaaaale
He
4
hehe
He
5
Wha...?
my eyes...
He
6
gasp
gasp
I ca–
can't
breathe...
He

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.



But it went back to
normal right away.

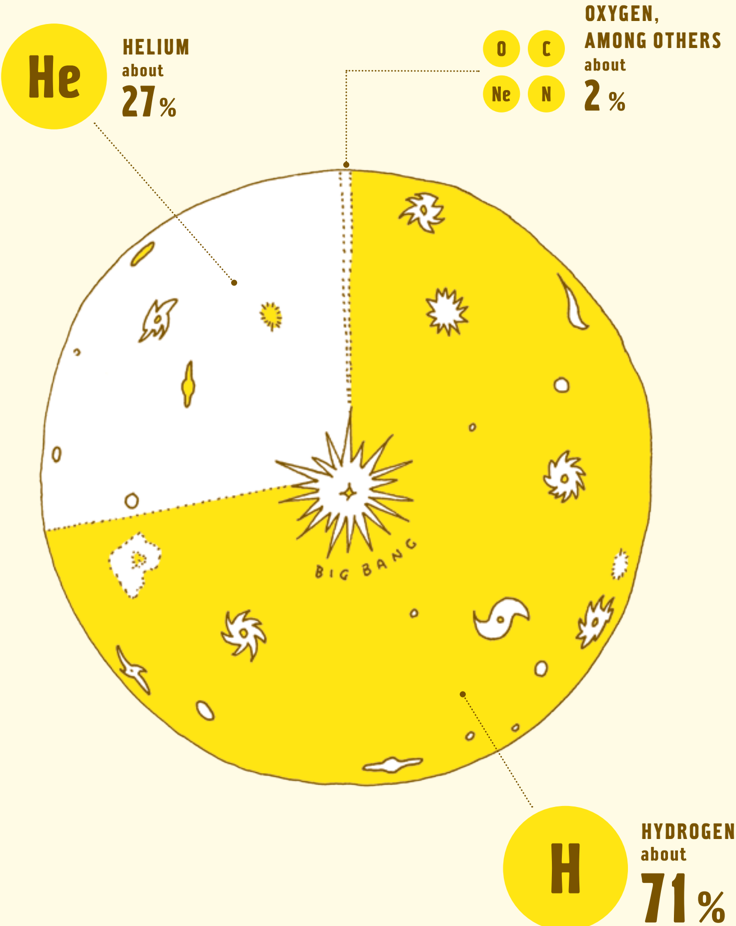
CONTENTS

1

ELEMENTS IN THE LIVING ROOM
リビングと元素

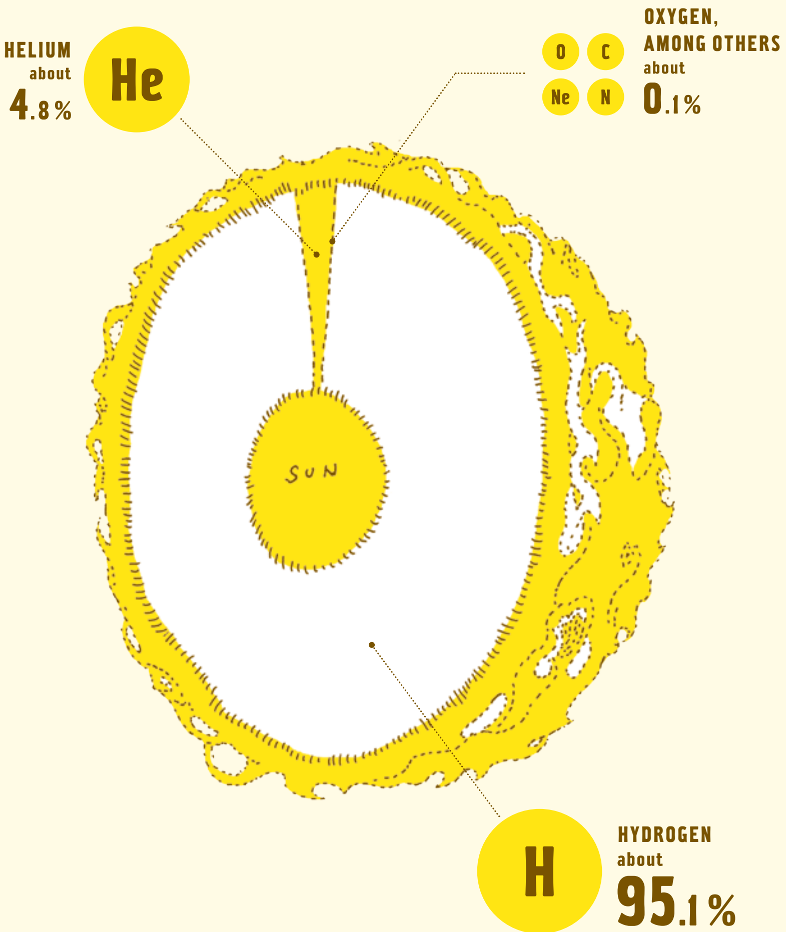
宇宙を構成する元素

ELEMENTS OF THE UNIVERSE



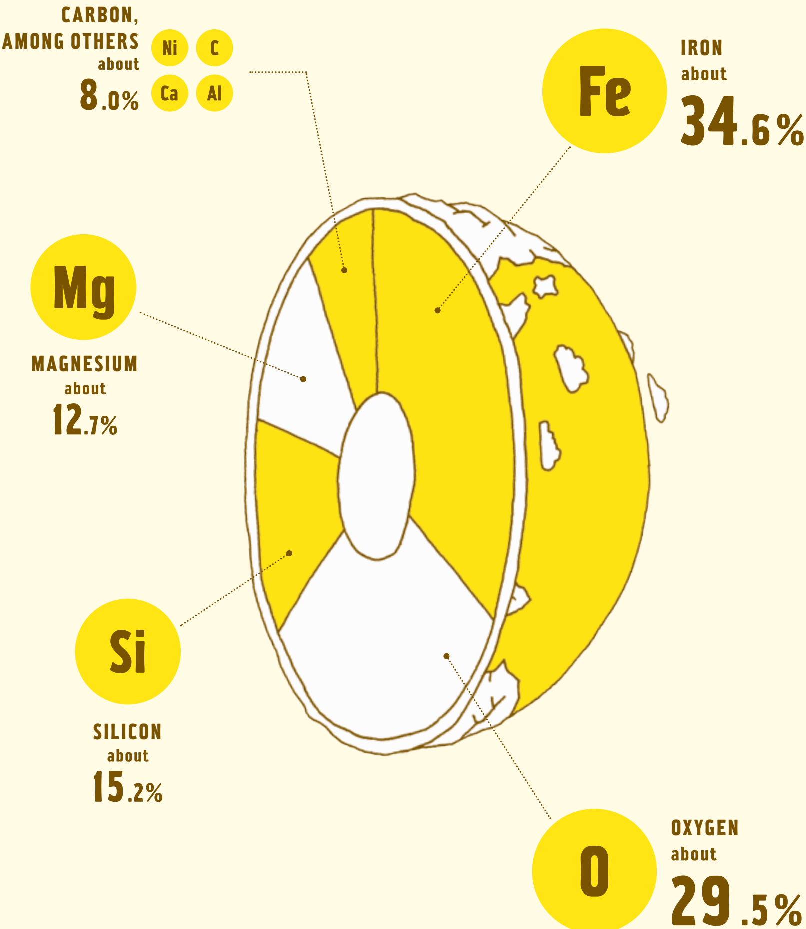
太陽を構成する元素

ELEMENTS OF THE SUN



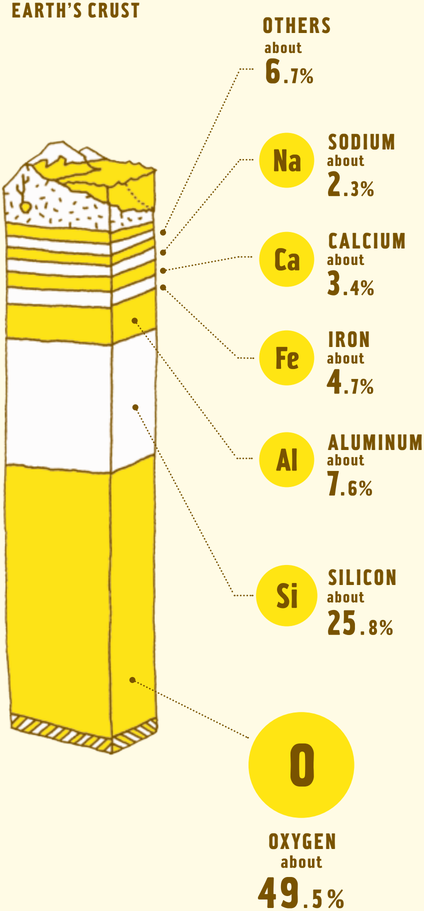
地球を構成する元素

ELEMENTS OF EARTH



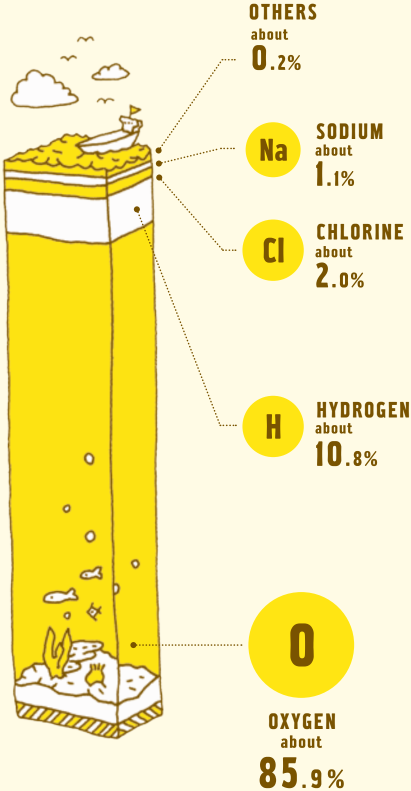
地殻を
構成する元素

ELEMENTS OF
EARTH'S CRUST



海水を
構成する元素

ELEMENTS OF
SEAWATER



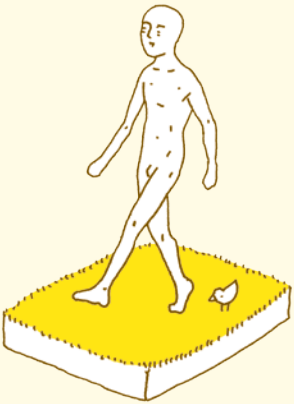
Elements fit perfectly in discussions of things like planets and outer space. But discussing our daily lives from the perspective of elements usually doesn't make much sense. In the last billion years or so, the elements of Earth haven't changed much. And it doesn't matter to the elements whether people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

C H O
N P S



LIVE

生きている

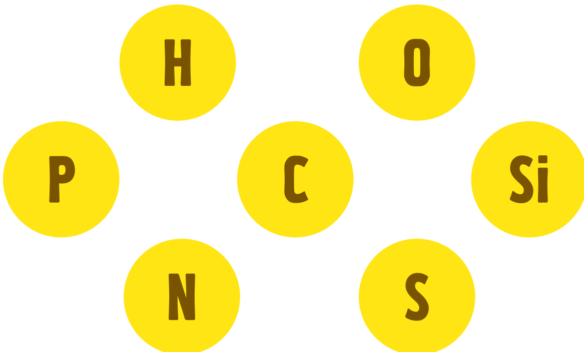
=

C H O
N P S

DEAD

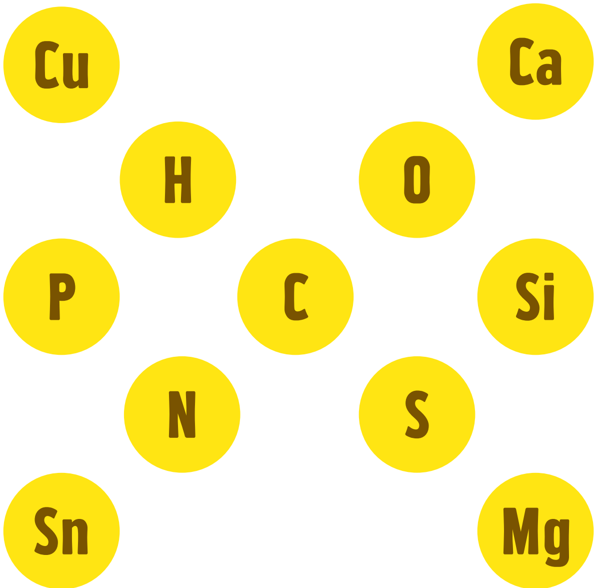
死んでいる

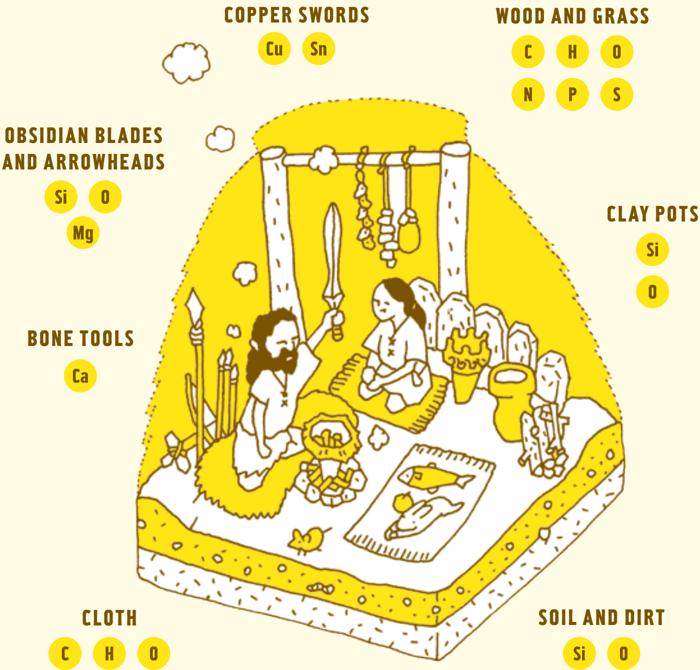
No change


H
O
P
C
Si
N
S

原始の生活

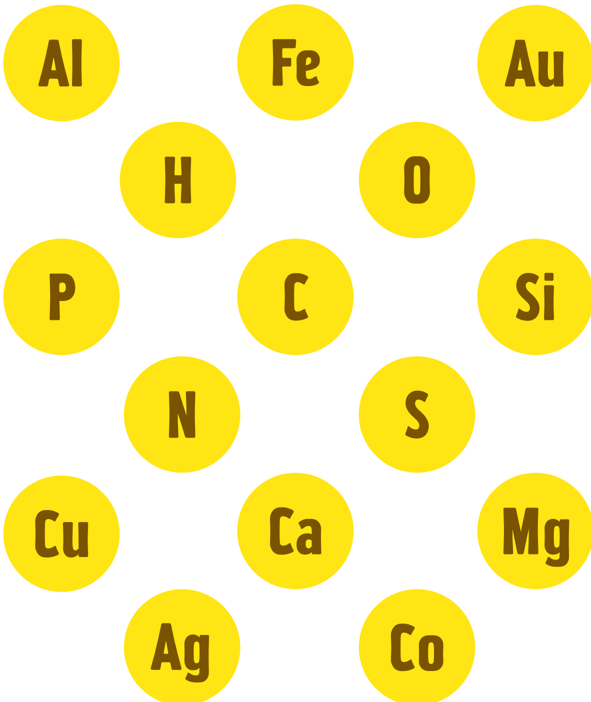
PRIMITIVE TIMES

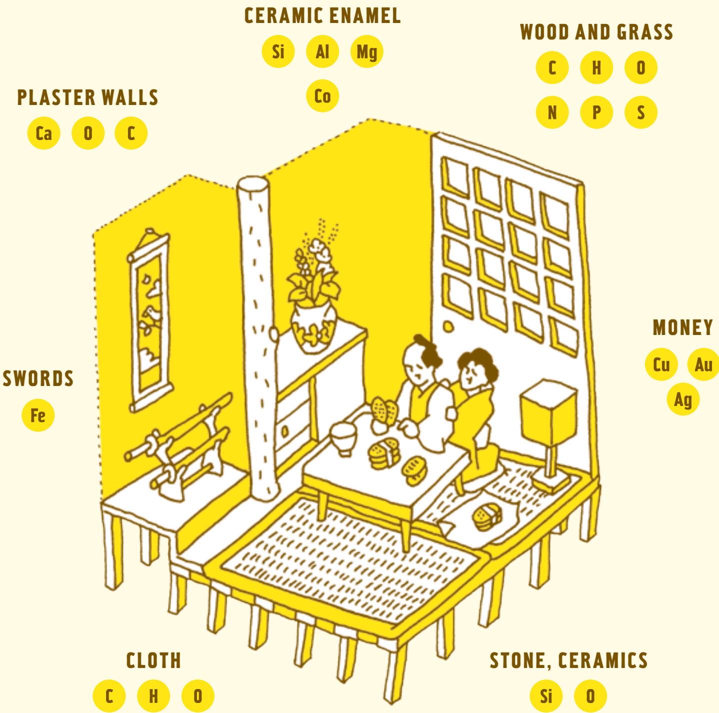

Cu
Ca
H
O
P
C
Si
N
S
Sn
Mg



古代の生活

ANCIENT TIMES


Al
Fe
Au
H
O
P
C
Si
N
S
Cu
Ca
Mg
Ag
Co



中世の生活

MEDIEVAL TIMES

As Fe W

Ru Zr In Sb

Al Cu Au

Ga H O Nd

P C Si

Li N S Hg

Br Ag Ni

Mn Co Ta Te

Mo Pb Kr


DVDS
Te Sb
FLUORESCENT HEAT LAMPS
Hg W Kr
ALUMINUM WINDOW FRAMES
Al
WOOD AND GRASS
C H O
N P S
LCDS
In
SPEAKERS
Zr Nd
GLASS
Si O
PLASTIC
C H O
N
LAPTOP COMPUTERS
Li Au Ni
Ag Cu Ru
Pb Ga Br
Fe Mo
MOBILE PHONES
As Li Mn
Co Ga Au
Ta
CLOTH
H O
C
CEMENT
Si O
STEEL FRAMES
Fe C

現代の生活

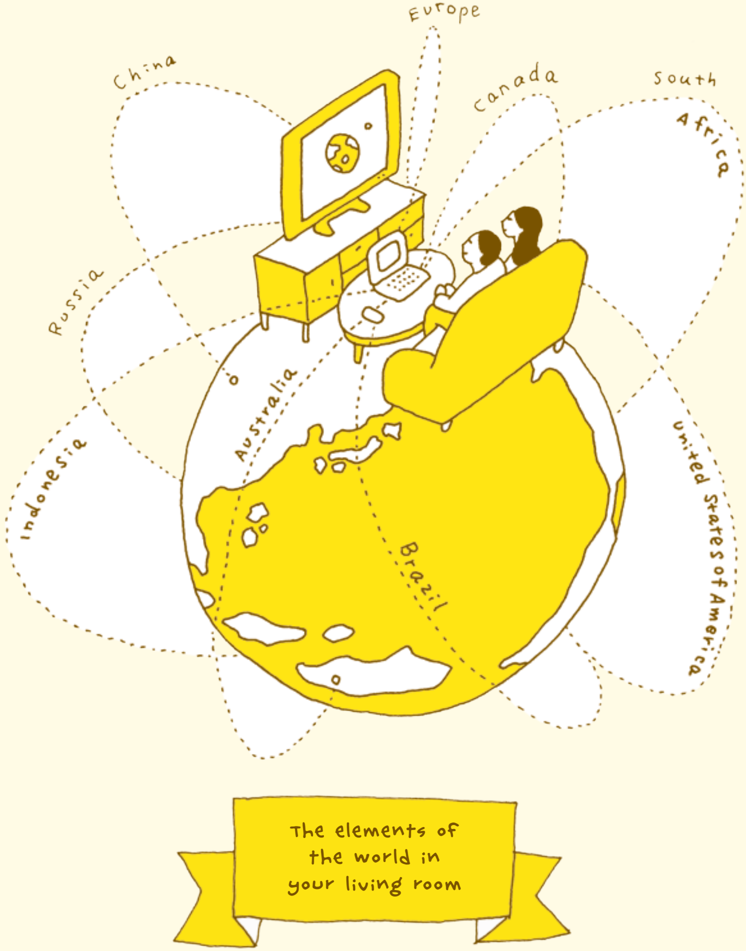
TODAY

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.

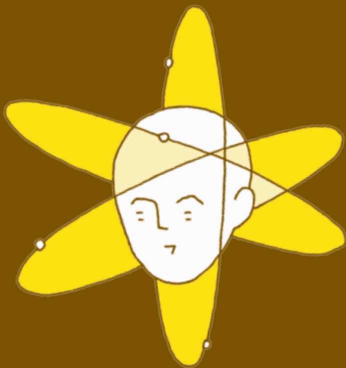
The indium used in our LCD TVs is from China, and plastic and vinyl are from oil drilled in the Middle East. (Oil is made up of carbon, mind you.) With the recent spread of the Internet, our borders have opened up with the help of copper and silicon dioxide (the elements that make up fiber-optic cables). 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.


Europe
China
Canada
South Africa
Russia
Australia
Indonesia
Brazil
United States of America
The elements of the world in your living room


You sure about this?
Duty calls...

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.

PERIOD / FAMILY	1	2	3	4	5	6	7	8	9
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

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.

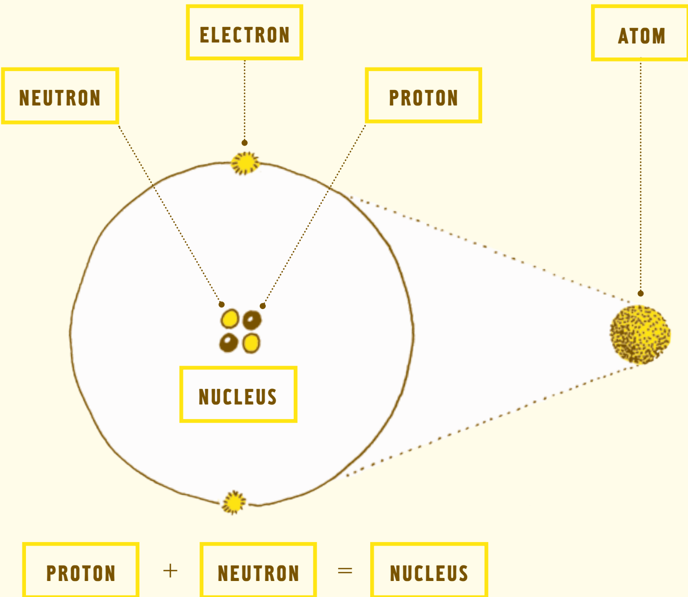
That's why we have the periodic table.

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.


Use it wisely.
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.

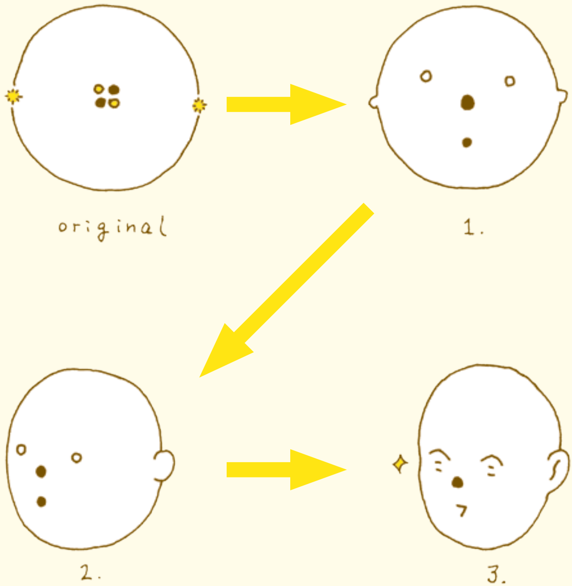
Atoms are made up of a nucleus and orbiting electrons. The nucleus consists of two kinds of particles called *protons* and *neutrons*.

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

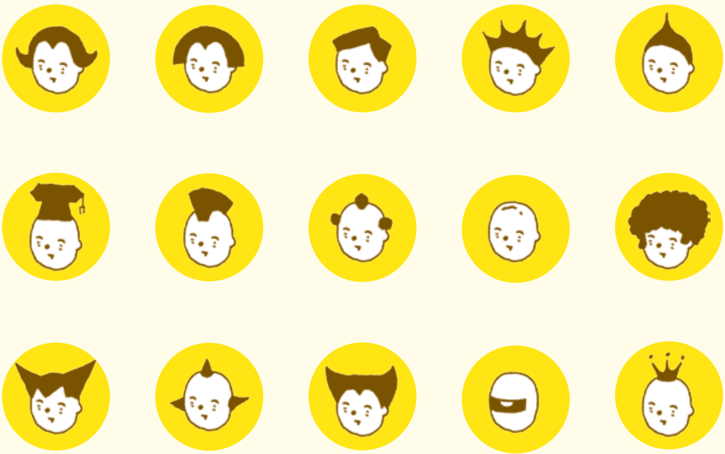


Each electron belongs to an electron shell. As the number of electrons increases, new shells are formed farther away from the nucleus. The electrons belonging to the outer shell are called *valence electrons*. Interactions between atoms are governed by their valence electrons, and many atomic properties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

元素のヘアースタイル

Hairstyles of the elements



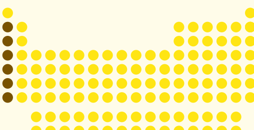
I've split the properties of the elements into 14 categories. (Hydrogen is in a class by itself.) They're mostly organized according to the families in the periodic table, but since some elements belonging to the same family exhibit different properties and elements of different families can be similar, 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.

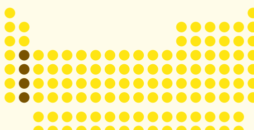


アルカリ土類金属

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.

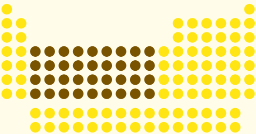


遷移金属

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.

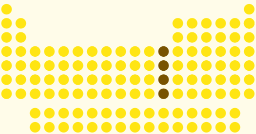


亜鉛族

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.

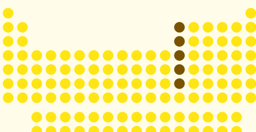


ホウ素族

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.

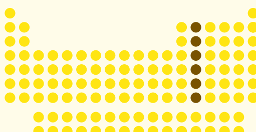


炭素族

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.

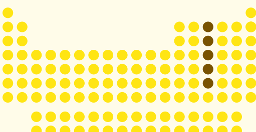


窒素族

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.

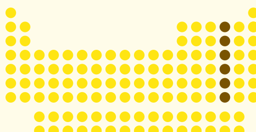


酸素族

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*.

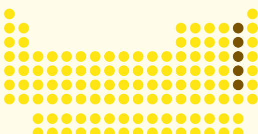


ハロゲン

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.

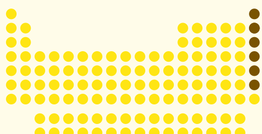


希ガス

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).

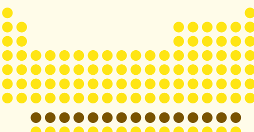


ランタノイド

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.

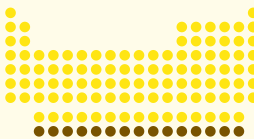


アクチノイド

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*.

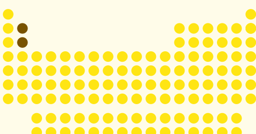


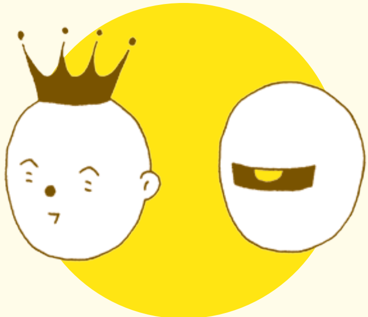
その他

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.



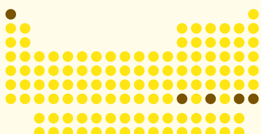


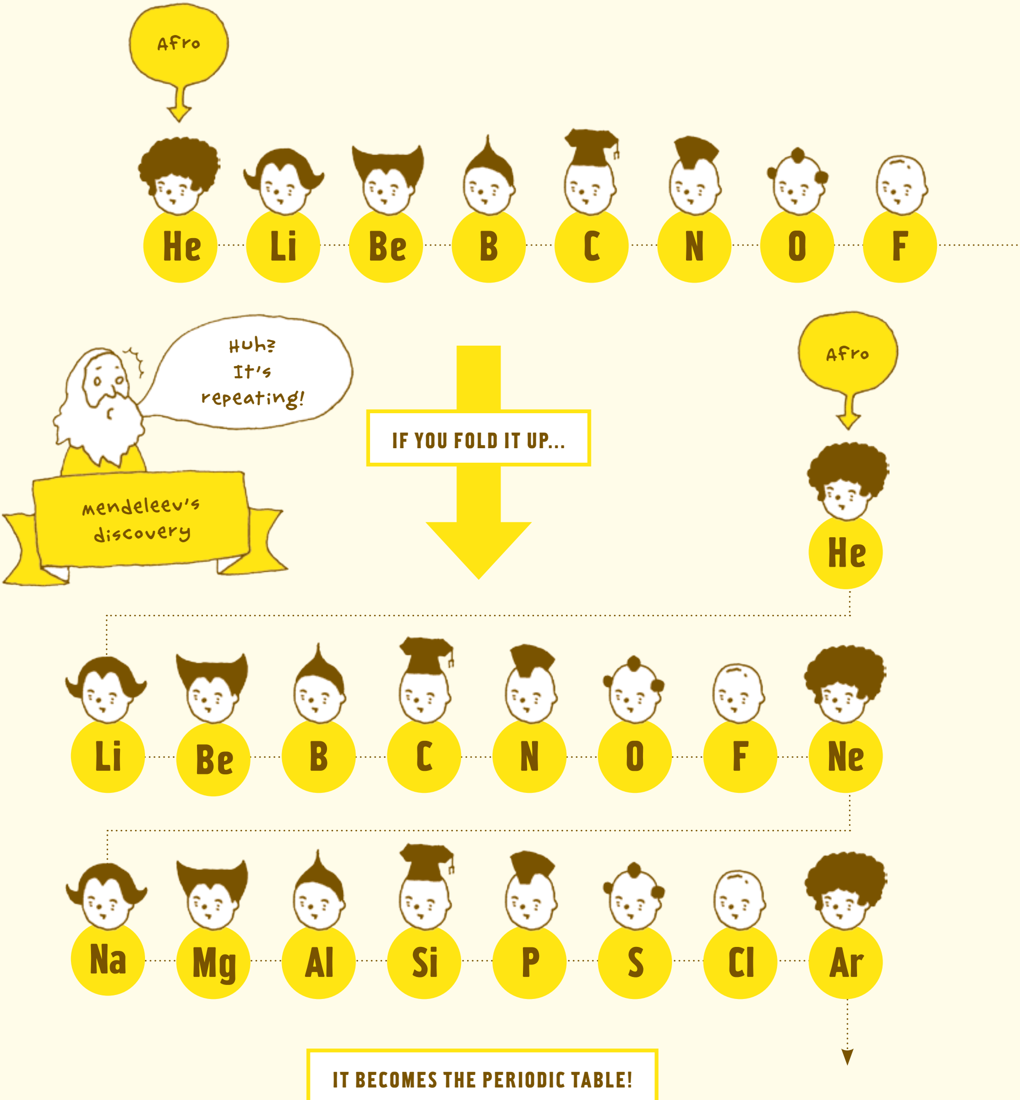
特別枠

Hydrogen and the Unun series

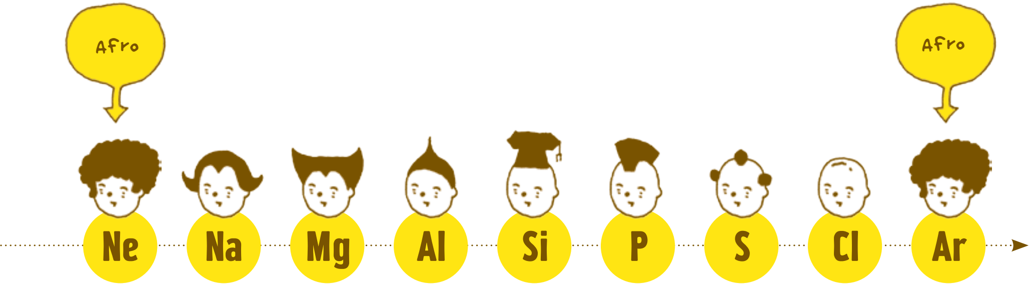
The supreme ruler
and the shrouded unknowns.

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.





Afro
He
Li
Be
B
C
N
O
F
Huh? It's repeating!
mendeleev's discovery
IF YOU FOLD IT UP...
Afro
He
Li
Be
B
C
N
O
F
Ne
Na
Mg
Al
Si
P
S
Cl
Ar
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?

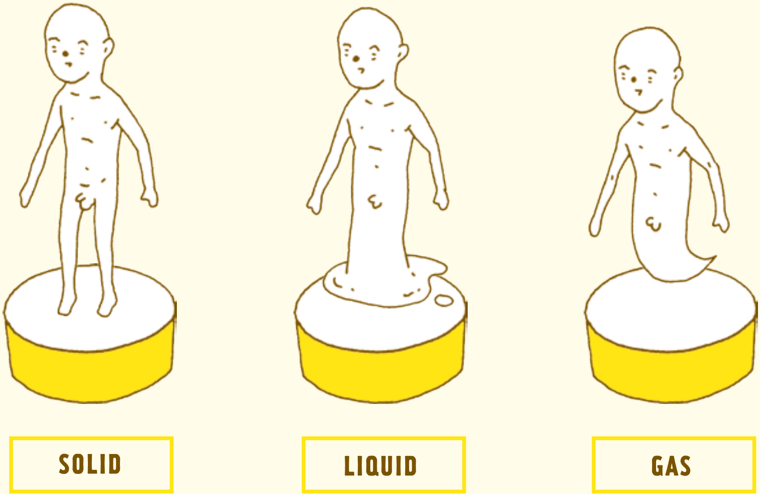
The elements, if arranged according to their atomic weight, exhibit an apparent periodicity of properties.

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

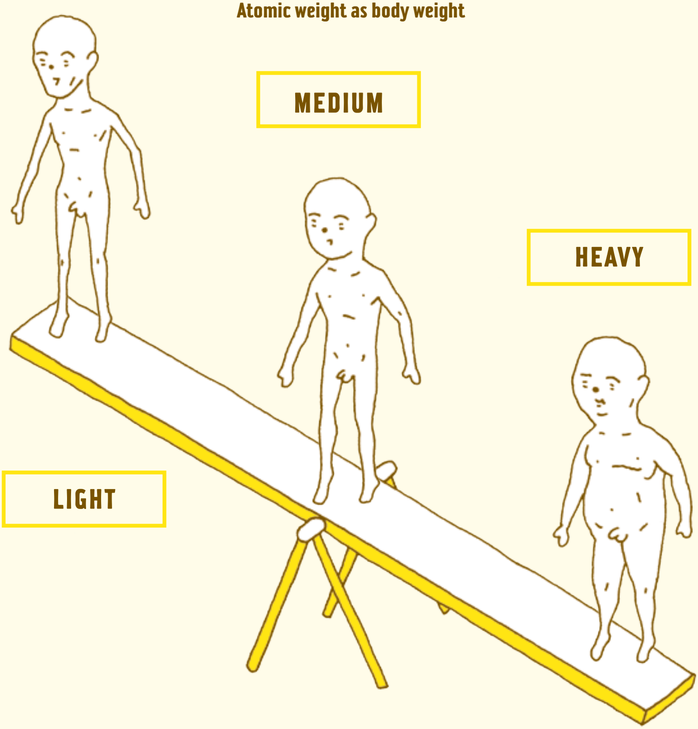


Let’s not stop at faces. Let’s do their bodies too!

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。

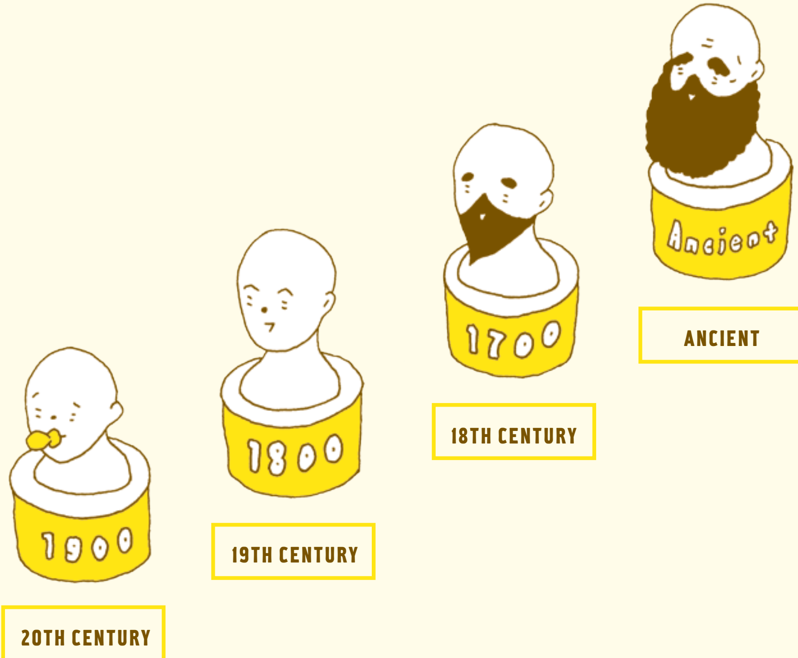
Atomic weight as body weight



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

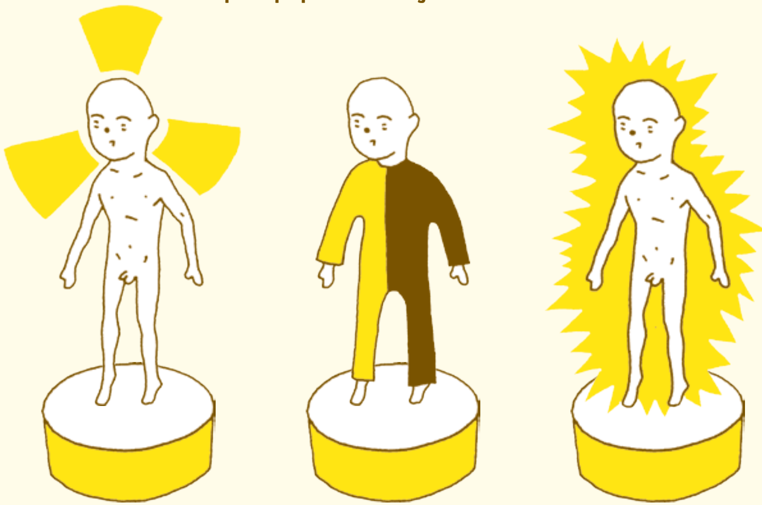


Some elements were discovered ages ago, and some synthetic ones were discovered only recently.

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

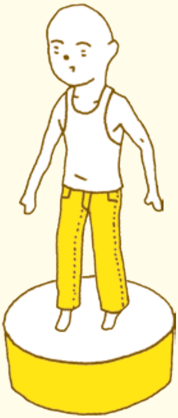
Elements used for luminous paint, fire-works, and fiber-optic cables.

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.

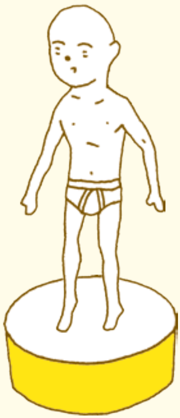
おもな使用用途を服装で。

Usage areas as clothes



MULTIPURPOSE

These versatile team players are popular in most application areas.

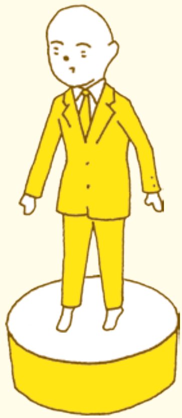


MINERAL

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

DAILY

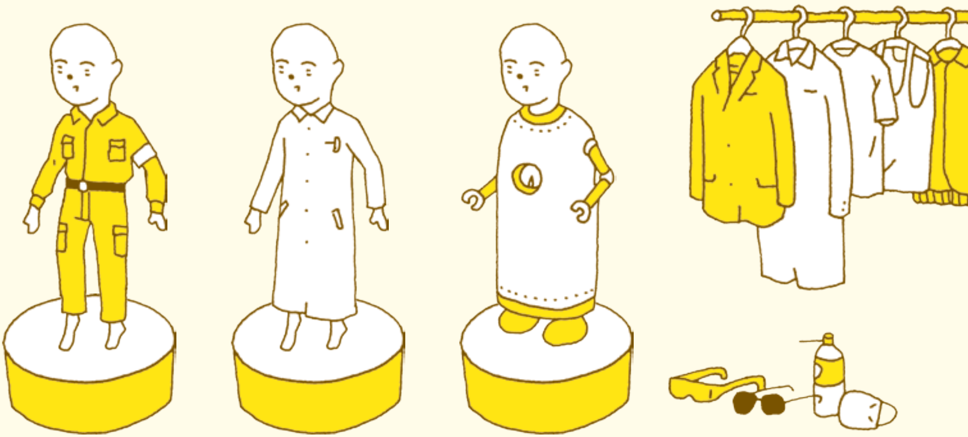
The nurturing materials we encounter every day in our kitchens and living rooms.



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

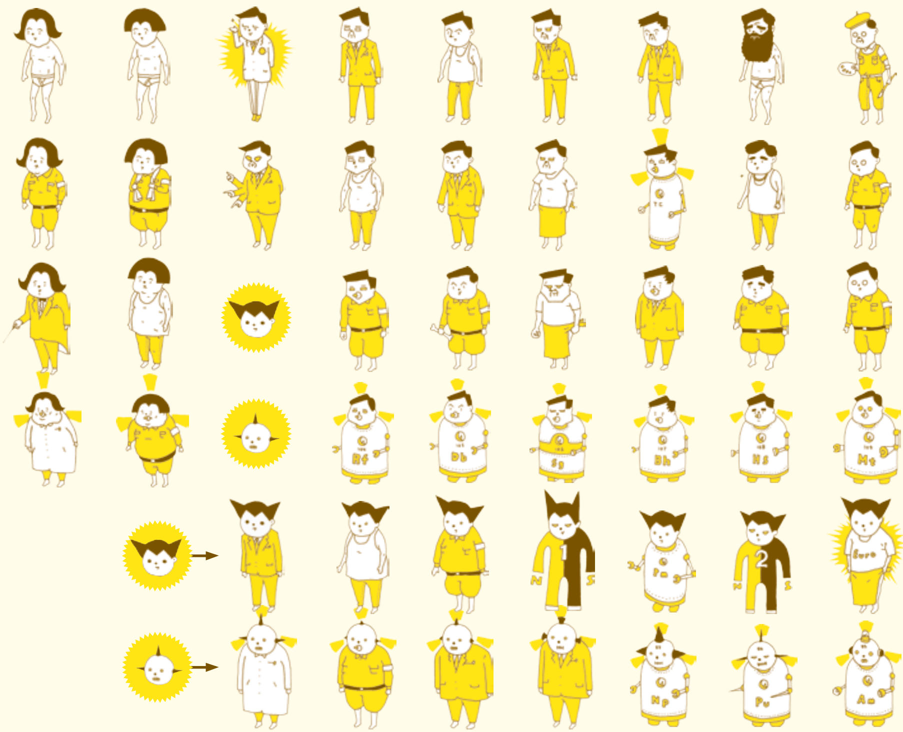
Man-made elements wear robot suits. (Used in Gundam construction.)

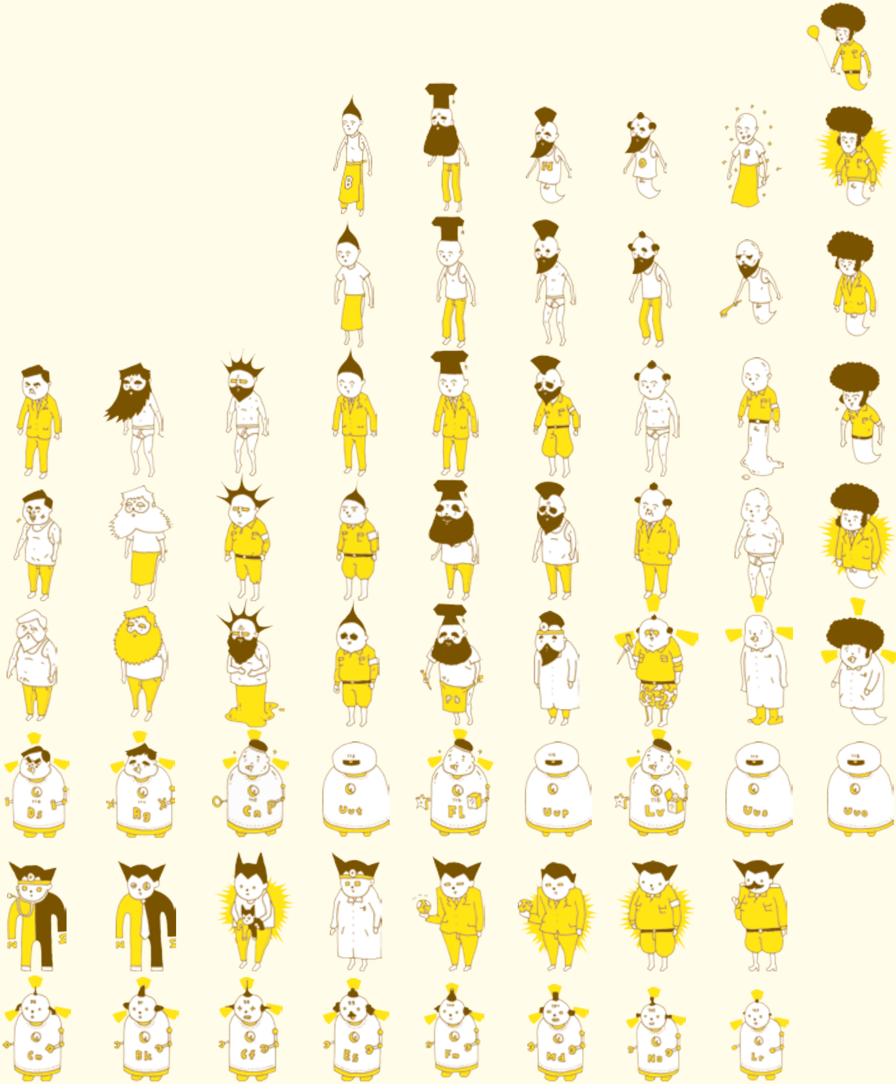
スーパー元素周期表

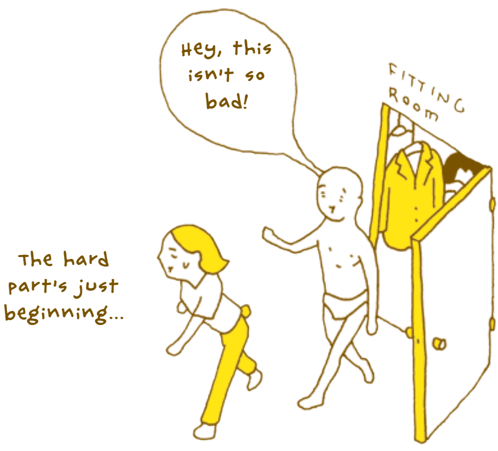
THE SUPER PERIODIC TABLE OF THE ELEMENTS

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.

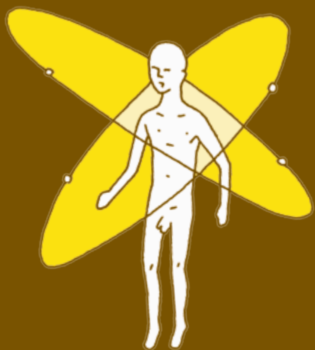
There is a poster in the back of this book with a larger version of this table, if you'd like to take a closer look.






Hey, this isn't so bad!
FITTING Room
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

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
CADMIUM


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

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 DARMSTADTIUM


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

MOLAR MASS

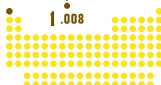
Amounts of elementary entities such as atoms, molecules, and isotopes are measured in moles, where 1 mole is equal to the number of atoms in 12 grams of carbon-12 (12C). The molar masses listed here are all rounded to four significant digits, and these are the official numbers recognized by IUPAC. Also,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

ELEMENT NAME

1

水素

Hydrogen



1

1

氫

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

ELEMENT CHARACTER

THE GOD ELEMENT THAT MAKES UP THE UNIVERSE

[háidrədʒən]

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 ℃

BOILING POINT
-252.87 ℃

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

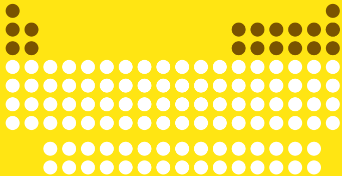
DENSITY

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

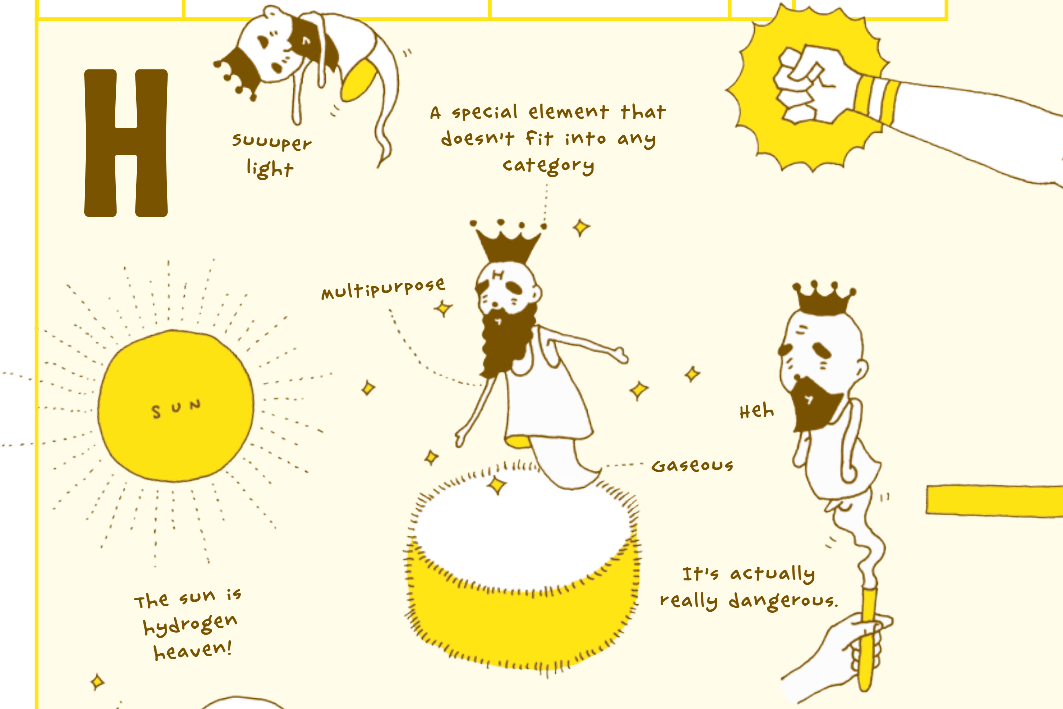
ATOMIC NUMBER

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
B
6
炭素
Carbon
7
N
窒素
Nitrogen
8
O
酸素
Oxygen
9
F
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	1.008	1 — 1	氢

H

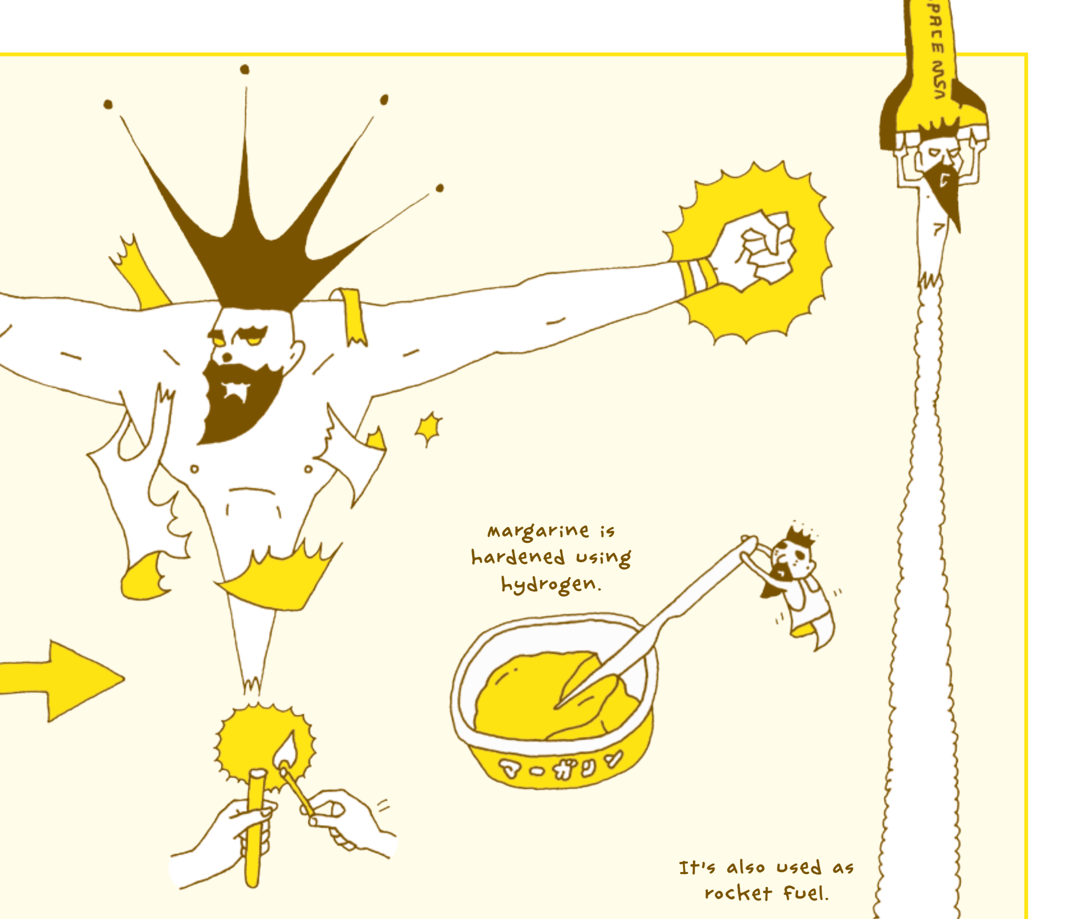


THE GOD ELEMENT THAT MAKES UP THE UNIVERSE

[háidrədʒən]

DISCOVERY YEAR : 1766

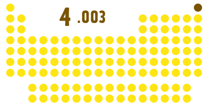
Hydrogen was by far the most common element in the first few minutes after the Big Bang, along with small amounts of deuterium and helium. These gases eventually formed the first stars. In a sense, hydrogen is the element that gave birth to all life. One of the most basic building blocks of all life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



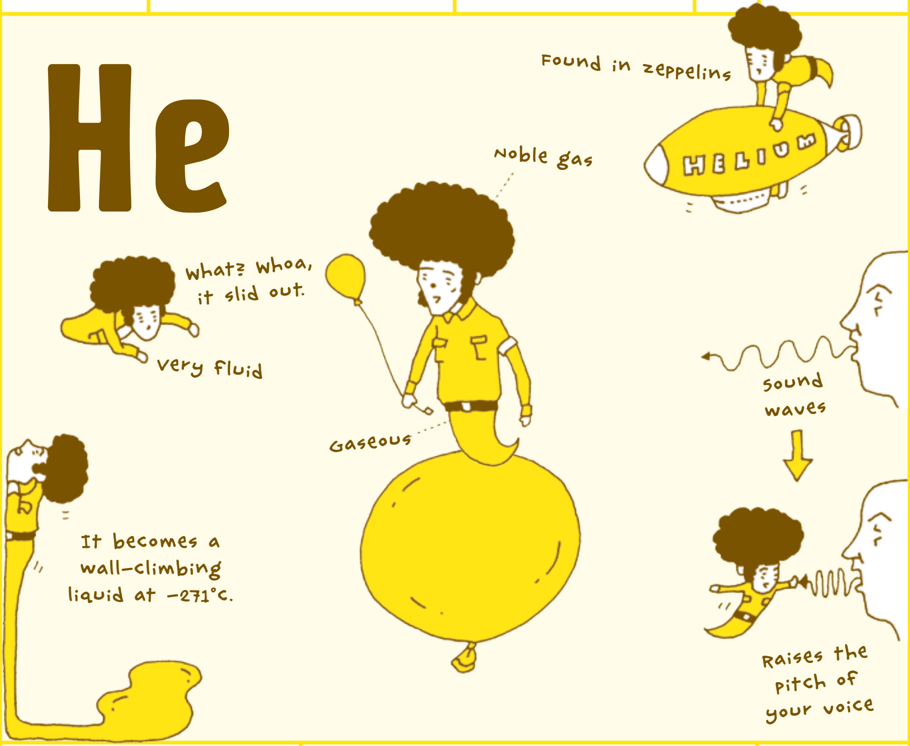
60% water, and the double helix in our DNA is strung together with hydrogen bonds. So if you're a believer, you might want to begin praying to hydrogen. One of the more recent application areas is clean energy, where it might replace fossil fuels. But even though it has helped us in so many ways, try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

MELTING POINT	-259.14 ℃
BOILING POINT	-252.87 ℃
DENSITY	0.00008988 (GAS FORM, 0°C) g/cm^3

2	ヘリウム Helium	4.003	1 18	氦



He



THE LIGHTHEARTED GAS THAT RAISES OUR SPIRITS AND OUR VOICES

[hí:liəm]

DISCOVERY YEAR : 1868

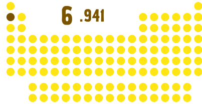
Children know it from funny voices and balloons. This ancient element could be found along with hydrogen minutes after the Big Bang. And without these two, no other elements could have been formed. They are the only two elements that are lighter than air, so maybe they're kind of like the leaders, looking 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) ℃

BOILING POINT
-268.934 ℃

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

3	リチウム Lithium	6.941	2 — 1	锂



Li

THE POWER SOURCE OF THE MOBILE AGE

【líθiəm】

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.

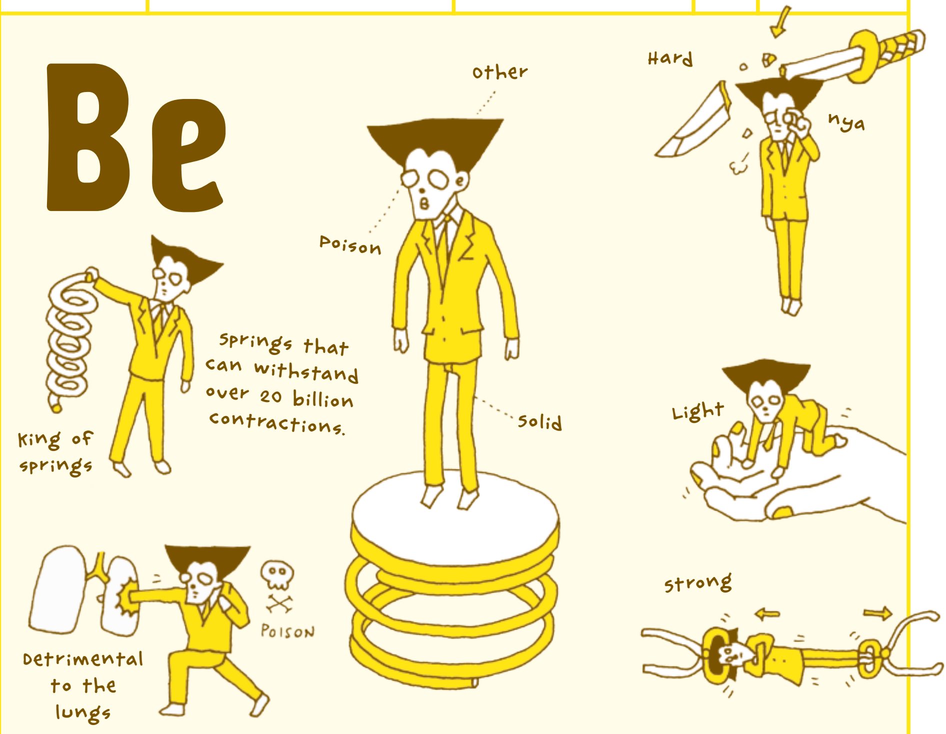
MELTING POINT
180.54 ℃

BOILING POINT
1340 ℃

DENSITY
0.534 (0°C) g/cm³

4	ベリリウム Beryllium	9.012	2 / 2	铍

Be



SUPER TALENTED! ELITE AND LEGENDARY!

[bəríliəm]

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 ℃

BOILING POINT 2970 (PRESSURIZED) ℃

DENSITY 1.8477 g/cm³

5	ホウ素 Boron	10.81	2 / 13	硼

B

HELPING OUR DAILY LIVES IN SO MANY WAYS

[bɔ̀:ran]

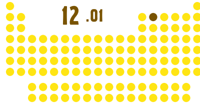
DISCOVERY YEAR: 1892

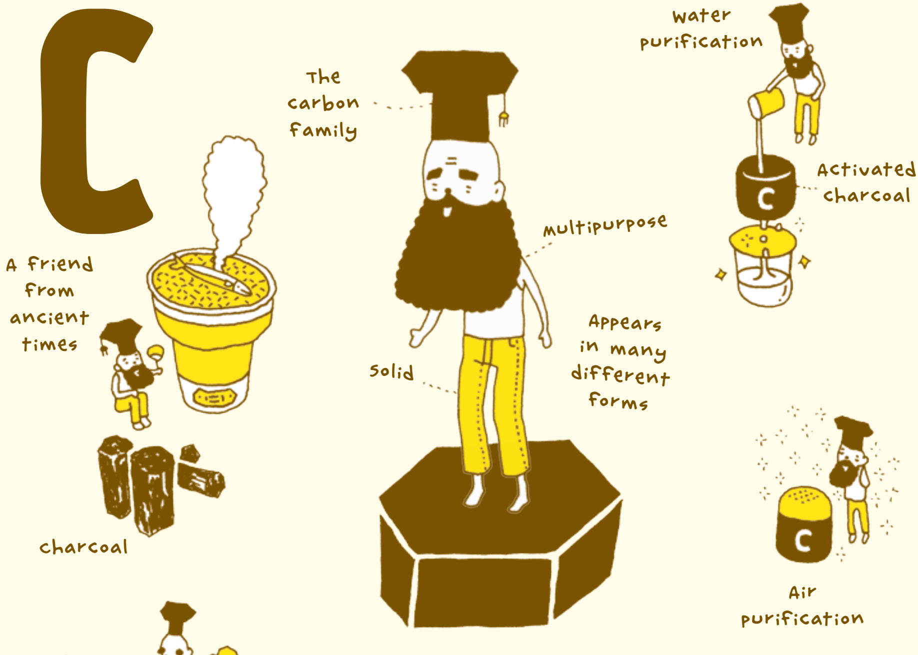
We mostly use boron in compounds. For example, the technical term for the heat-resistant glass Pyrex is *borosilicate glass*, created by adding boron oxide to keep the glass from swelling and shrinking. Harder diamonds can be created by combining boron with carbon. Finding new boron combinations is a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

MELTING POINT
2300 ℃

BOILING POINT
3658 ℃

DENSITY
2.34 (TYPE B) g/cm³

6	炭素 Carbon		2 14	碳



PART OF EVERY LIVING THING

【Ká:rbən】

DISCOVERY YEAR: ANCIENT

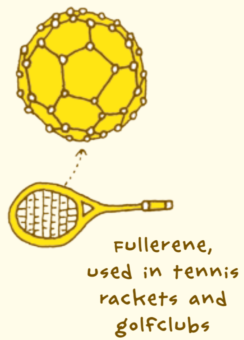
Carbon is the building block of all life. One could argue that the food chain should instead be called something like "the carbon tug-of-war." Carbohydrates, proteins, and all the other nutrients that we require are made up of carbon compounds. The same is also true of our cells, DNA, and the plants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

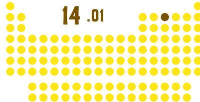
photosynthesis.) The fourth most abundant element in the universe, carbon comes in many forms, from the graphite in our pencils to diamonds. The forms are so different that it's hard to believe that they're made from the same element. It appears today in oil, plastics, clothes, and medicines. It has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

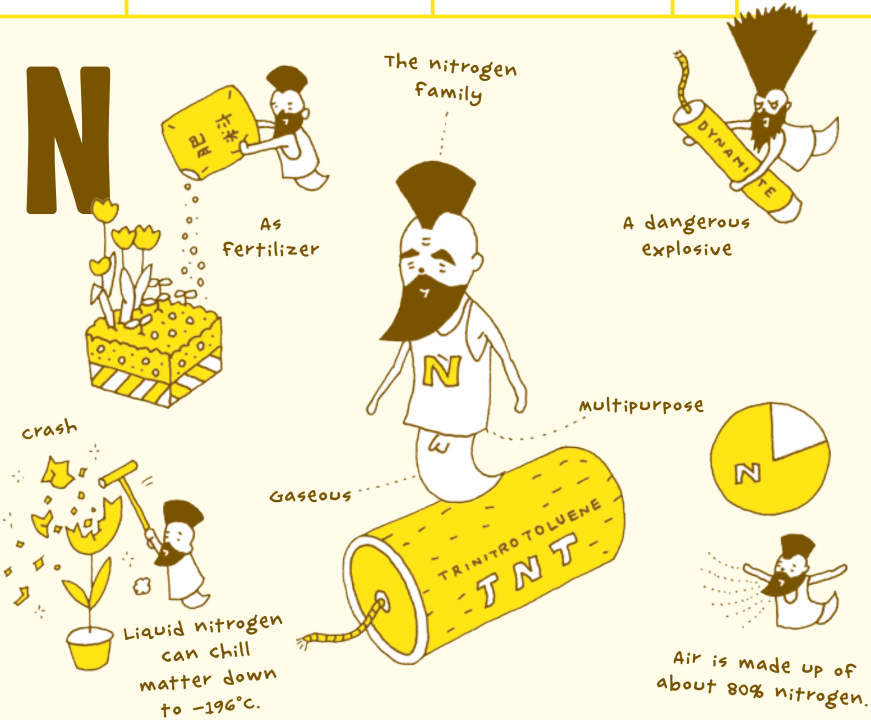
MELTING POINT
3550 (DIAMOND) ℃

BOILING POINT
4827 (SUBLIMATION) ℃

DENSITY
3.513 (DIAMOND) g/cm³



7	窒素 Nitrogen	 14.01	2 15	氮



LOOKS FRIENDLY AND COOL, BUT CAN BE DANGEROUS

[náitrədʒən]

DISCOVERY YEAR: 1772

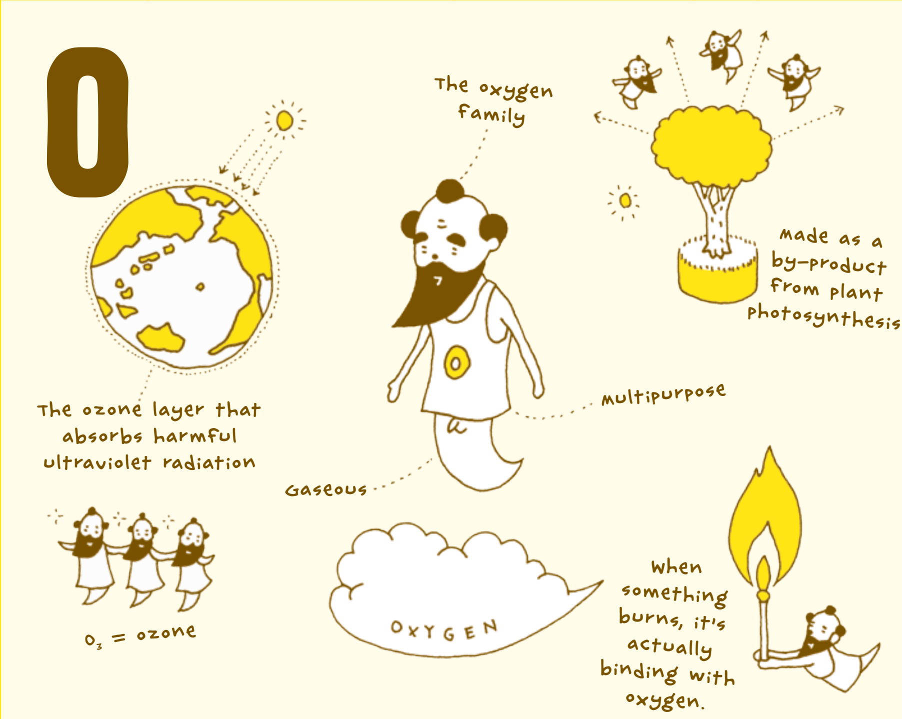
Making up about 80% of the air we breathe, nitrogen is also the main component of our DNA and the amino acids that make up the proteins in our bodies. It may seem docile, but most explosives—like nitroglycerin and dynamite—are made using nitrogen compounds. Combined with oxygen, it's also a major pollutant.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

MELTING POINT
-209.86 ℃

BOILING POINT
-195.8 ℃

DENSITY
0.0012506
(GAS FORM, 0°C)
g/cm^3

8	酸素 Oxygen	16.00	2 / 16	氧



THE SINGLE-MINDED ELEMENT THAT PROTECTS EARTH

[áksidʒən]

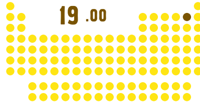
DISCOVERY YEAR: 1774

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 ℃

BOILING POINT -182.96 ℃

DENSITY 0.001429 (GAS FORM, 0°C) g/cm³

9	**フッ素** **Fluorine**	 19.00	2 — 17	氟

THE TIDY POISON

【flúəriːn】

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.

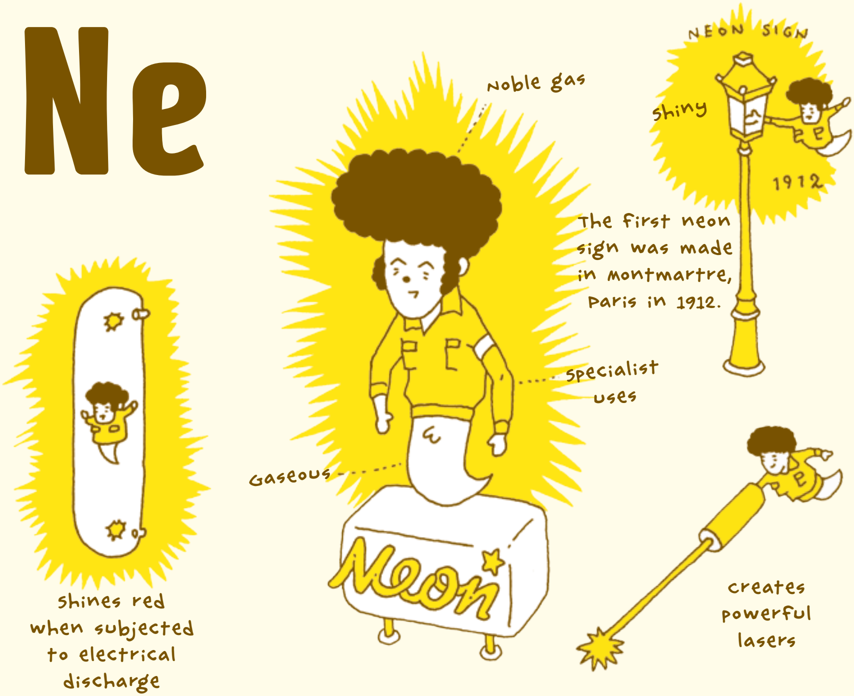
MELTING POINT
-219.62 ℃

BOILING POINT
-188.14 ℃

DENSITY
0.001696 (GAS FORM, 0°C) g/cm^3

10	ネオン Neon	20.18	2 / 18	氖

Ne



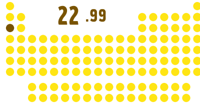
THE BEACON OF THE NIGHT WAS BORN IN PARIS

[ní:an]

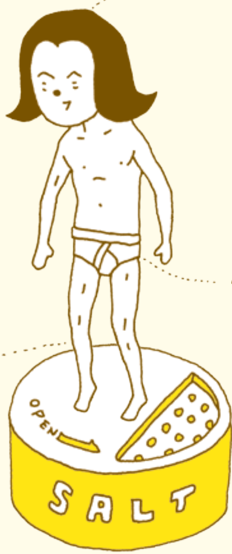
DISCOVERY YEAR: 1898

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 ℃
BOILING POINT	-246.05 ℃
DENSITY	0.00089994 (GAS FORM, 0°C) g/cm^3

11	ナトリウム Sodium	 22.99	3 1	钠

Na

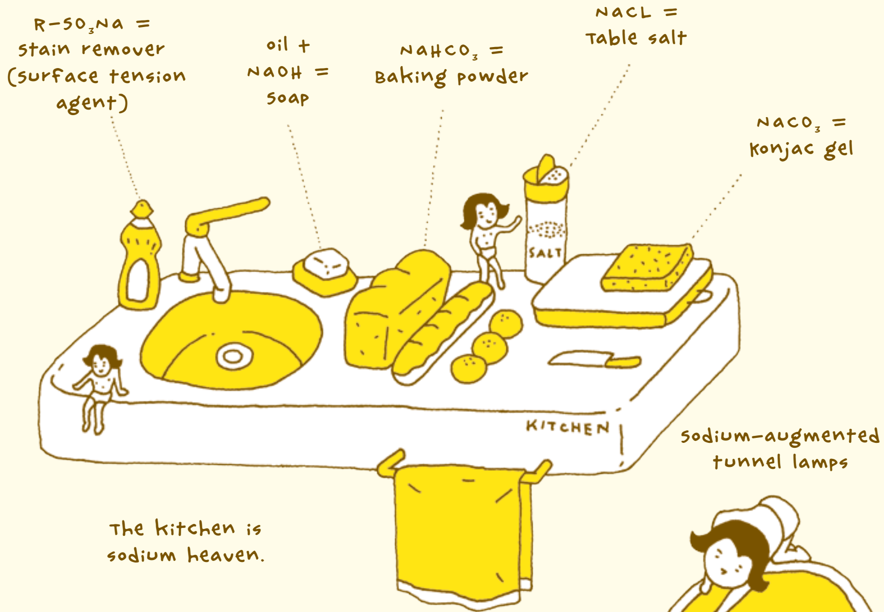


MOTHER'S FAVORITE, GOOD FOR BOTH FOOD AND CLEANING!

[sóudiəm]

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



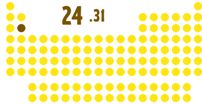
carbonates. But this loved and popular character also has some dangerous properties. Many sodium compounds are highly water soluble, but if pure sodium comes in contact with water, it explodes, proving it to be something of a gremlin element! That's why it's popular to store it in oil or some other non-water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

MELTING POINT	97.81 ℃
BOILING POINT	883 ℃
DENSITY	0.971 g/cm^3

12

マグネシウム Magnesium

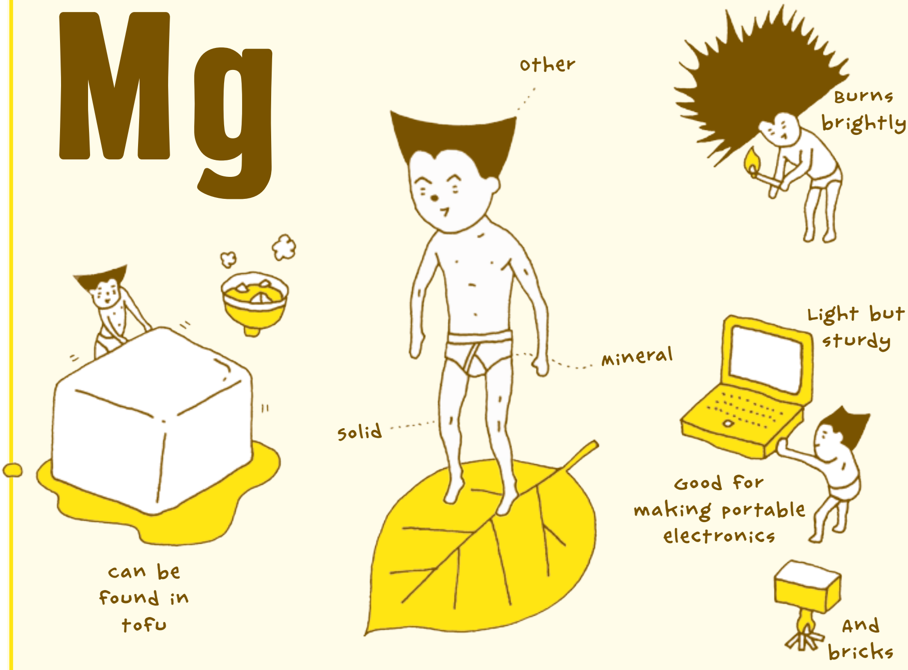
24.31



3
2

镁

Mg



THE SUPER SKILLED HONOR STUDENT?!

【mægní:ziəm】

DISCOVERY YEAR: 1808

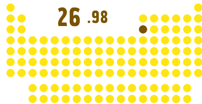
Lighter than aluminum and as strong as steel, magnesium has good electrical and magnetic insulation properties and does not retain heat. That's why it's perfect for laptop and cell phone shells. But magnesium is not just a techie element, as it's found in abundance both in tofu and in the chlorophyll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

MELTING POINT
650 ℃

BOILING POINT
1095 ℃

DENSITY
1.738 g/cm³

13	アルミニウム **Aluminum**	26.98	3 / 13	铝



Al

THE MOST COMMON METAL ON EARTH

【əl'u:mínəm】

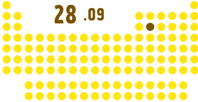
DISCOVERY YEAR: 1807

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.

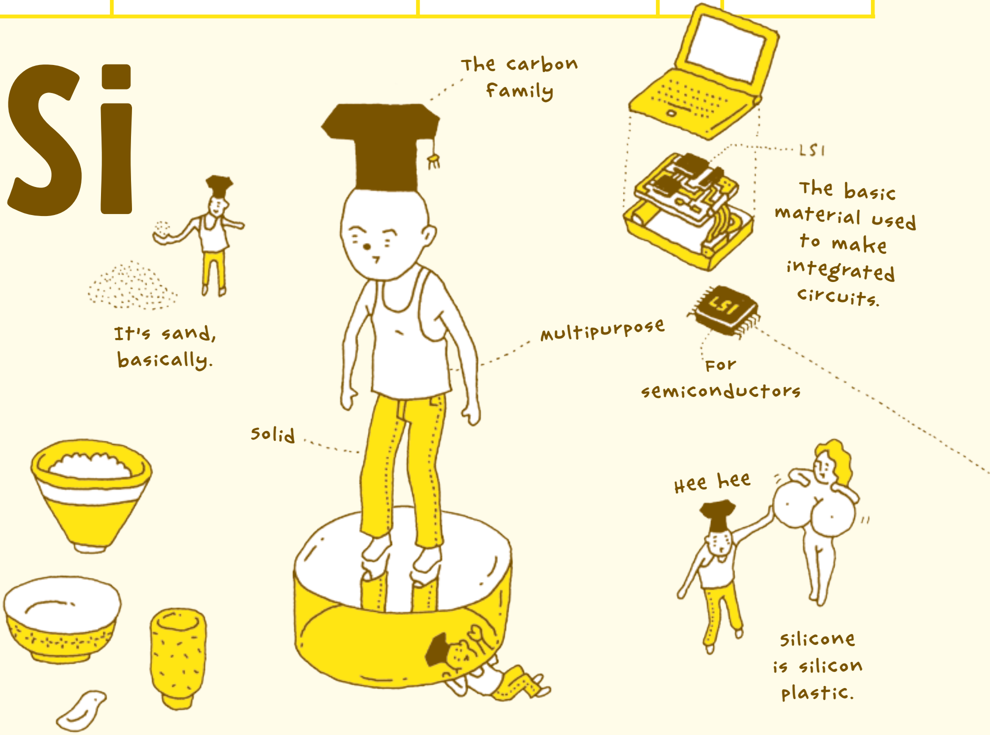
MELTING POINT
660.37 ℃

BOILING POINT
2520 ℃

DENSITY
2.698 g/cm³

14	ケイ素 Silicon	28.09 	3 — 14	硅

Si

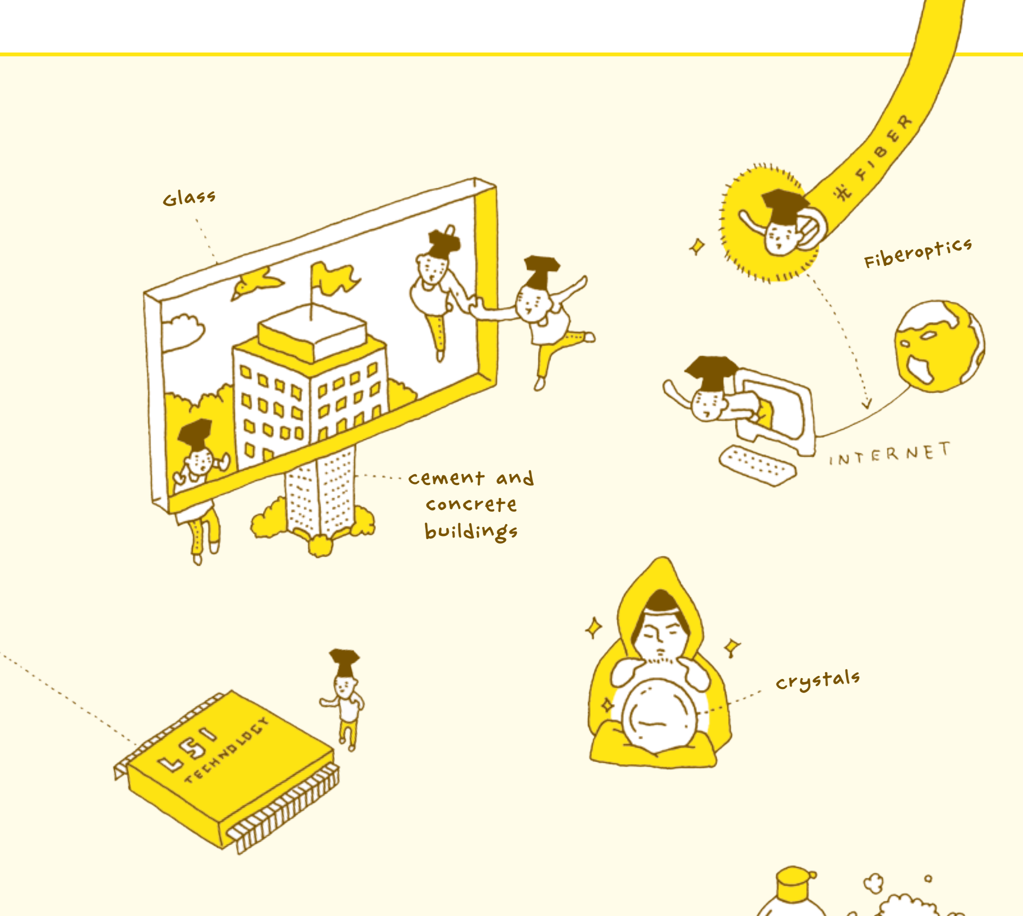


THE DIGITAL ARTISAN FROM THE DESERT

[sílikən]

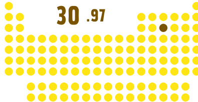
DISCOVERY YEAR: 1823

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

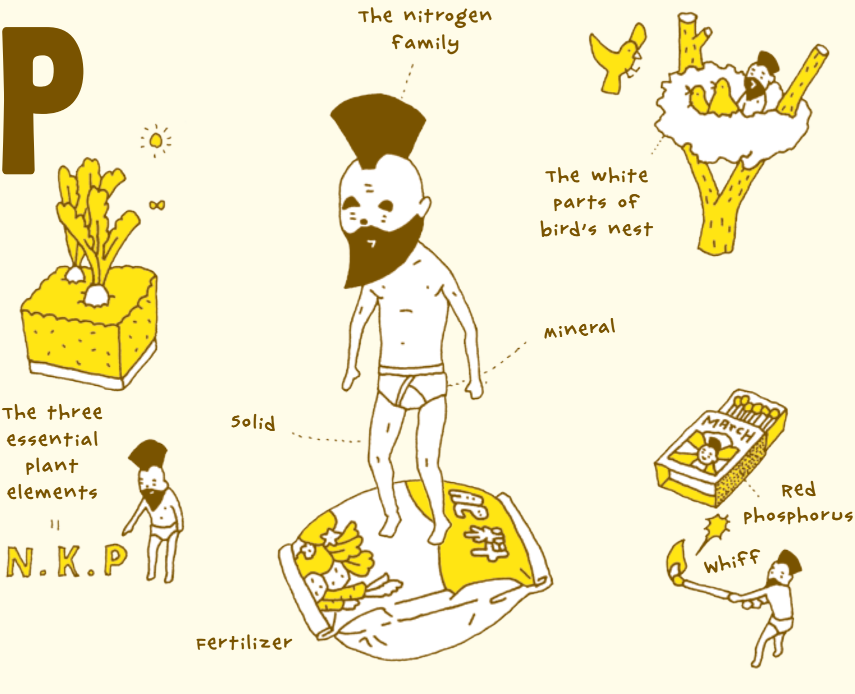


rubber is used to make baby bottle caps and breast implants, among other things. Silicon dioxide-rich sand has heat-resistant properties and is used to make bricks and building walls. The insulation material asbestos was popular at the end of the 19th century, but now we know that asbestos fibers can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

MELTING POINT	1410 ℃
BOILING POINT	2355 ℃
DENSITY	2.329 g/cm^3

15	リン Phosphorus	 30.97	3 / 15	磷

P



IT ALL STARTED WITH PEE!
THE LIVELY ELEMENT

[fásfərəs]

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)
℃

BOILING POINT
279.9
(WHITE PHOSPHORUS)
℃

DENSITY
1.82
(WHITE PHOSPHORUS)
g/cm^3

16	硫黄 Sulfur	32.07	3 16	硫

THE STINKY VITALITY SOURCE!

[sʌlfər]

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) ℃
BOILING POINT	444.674 ℃
DENSITY	2.07 (CRYSTALLINE FORM) g/cm^3

17	塩素 Chlorine	35.45	3 / 17	氯

Cl

KILLS BACTERIA!
THE UNRIVALED CLEAN-FREAK

[klɔ́ːriːn]

DISCOVERY YEAR: 1774

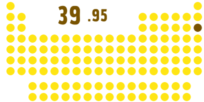
Chlorine is commonly used in water purification plants and pool water as an antibacterial agent. But while it has more or less eradicated epidemic water diseases such as typhoid and cholera, it was also used as a chemical weapon during World War I. It is also used in many everyday items, such as PVC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

MELTING POINT
-100.98 ℃

BOILING POINT
-33.97 ℃

DENSITY
0.003214 (0℃) g/cm³

18	アルゴン Argon	39.95	3 18	氩



Ar

AFFABLE AND EASYGOING

【á:rgan】

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 ℃

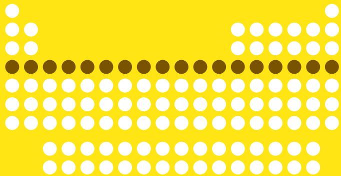
BOILING POINT
-185.86 ℃

DENSITY
0.001784
(GAS FORM, 0°C)
g/cm^3

周期

PERIOD

4



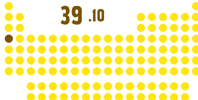
原子番号

ATOMIC NUMBER

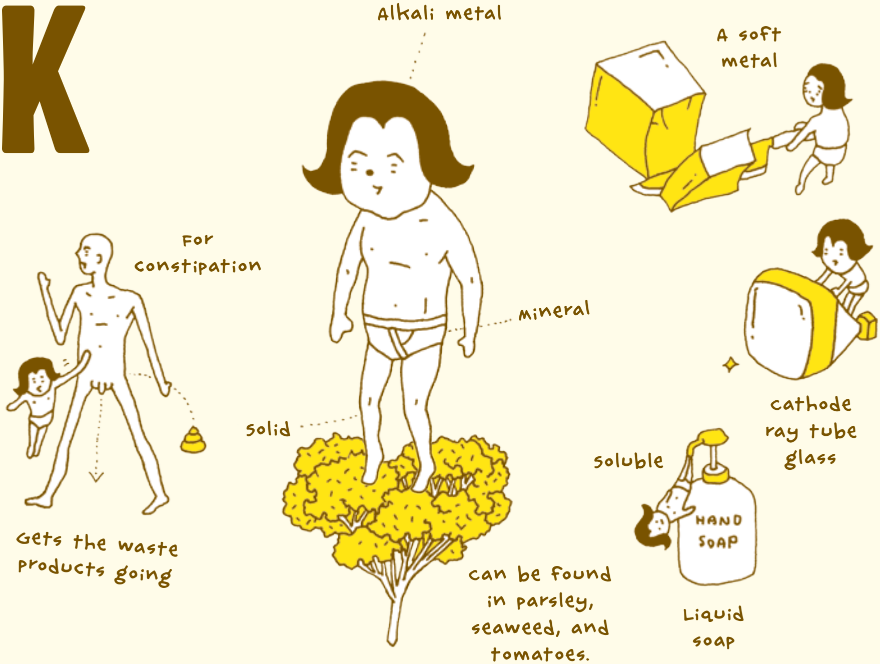
19→36

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 Potassium	39.10	4 — 1	钾



K

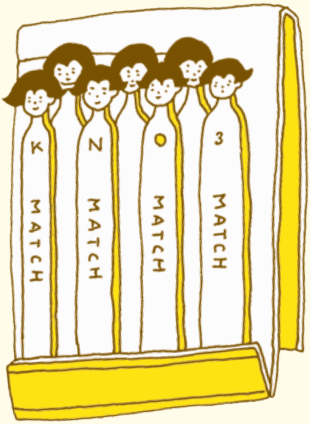


THE ULTRA-LIVELY MINERAL ELEMENT

【pətǽsiəm】

DISCOVERY YEAR: 1807

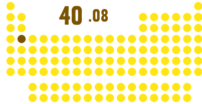
Potassium is a mineral that is vital to our bodies and is also one of three main fertilizers used in agriculture. Both potassium and sodium use our cells as their workplace, where they fire nerves and contract muscles. Potassium can also form a multitude of salts with varying properties, depending on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



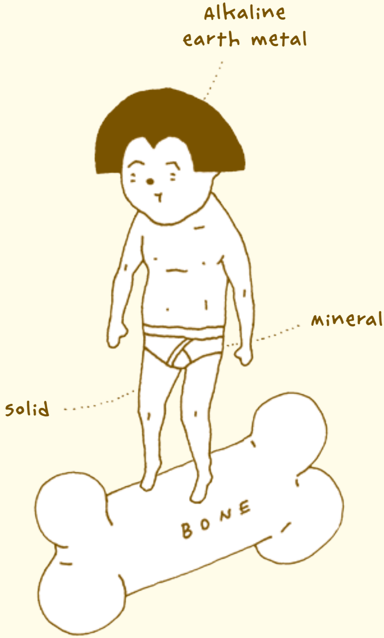
potassium fatty acid salts are used in the production of soaps. Potassium nitrate (an ionic salt) is used in fireworks and gunpowder. But even though it's found in many places around the house, potassium is the basis for some very famous poisons. In fact, the poison that we call cyanide is actually a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

MELTING POINT	63.65 ℃
BOILING POINT	774 ℃
DENSITY	0.862 (-80°C) g/cm³

20	カルシウム Calcium	40.08	4 / 2	鈣



Ca



BONES AND SHINING TEETH, THE WHITE-CLAD WORKER

【kǽlsiəm】

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

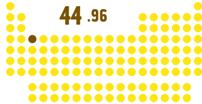
technology to manufacture more natural tooth prostheses for people who don't like amalgam fillings. Does it feel kind of strange, knowing that almost all of the minerals in our bodies are actually different kinds of metal? One fun fact is that the nutrients known as vitamins often get discussed together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

MELTING POINT	839 ℃
BOILING POINT	1484 ℃
DENSITY	1.55 g/cm^3

21

スカンジウム

Scandium

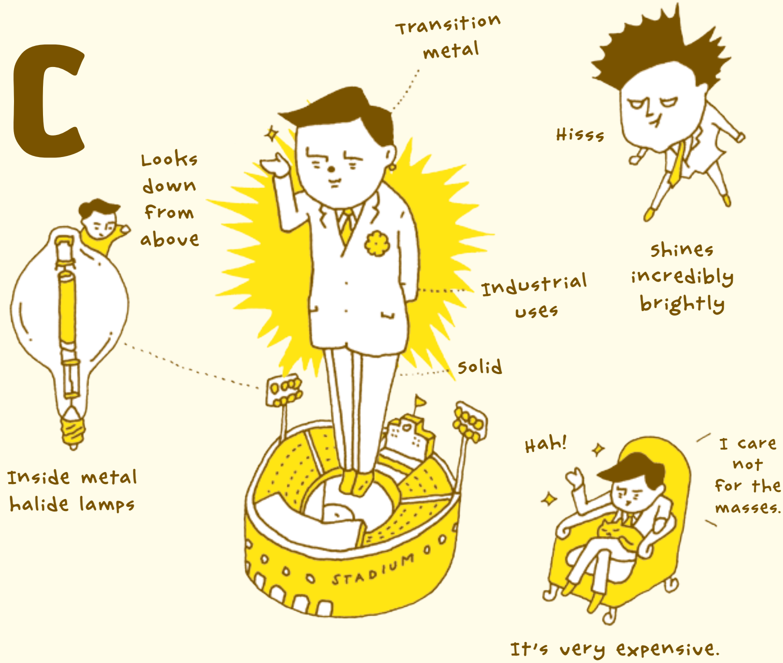


4

3

鈧

Sc



PRICEY BUT BLAND, THE SMALL-TIME CELEBRITY

【skǽndiəm】

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 ℃

BOILING POINT

2831 ℃

DENSITY

2.989 g/cm^3

22

チタン

Titanium

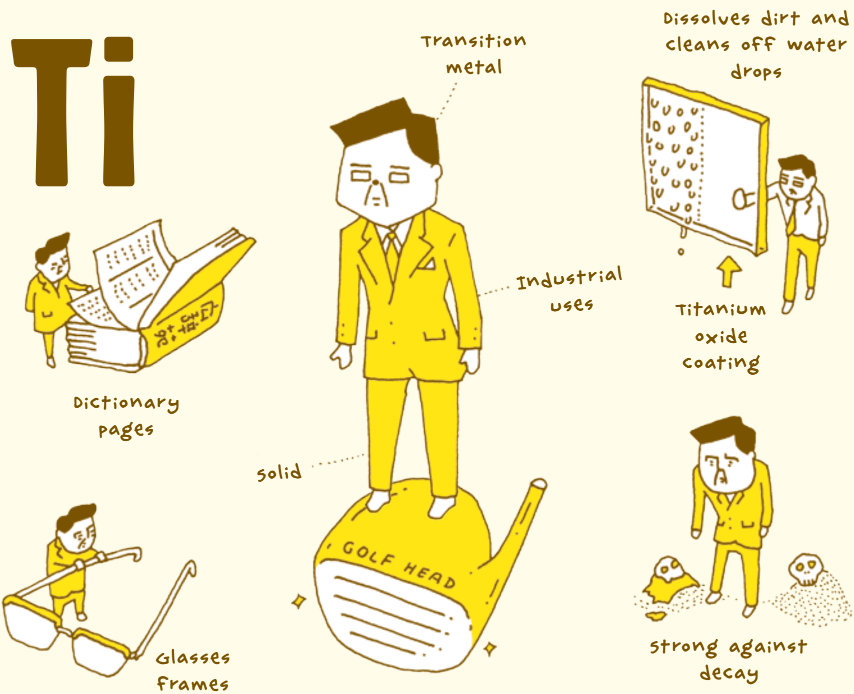
47.87

4

4

钛

Ti



THE SUPER-USEFUL SMART METAL

[taitéiniəm]

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

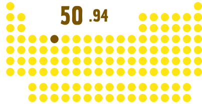
1760 ℃

BOILING POINT

3287 ℃

DENSITY

4.54 g/cm^3

23	バナジウム Vanadium	50.94 	4 — 5	钒

V

THE CONTROVERSIAL OCEANIC MINERAL

【vənéidiəm】

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 ℃

BOILING POINT
3377 ℃

DENSITY
6.11 (19℃) g/cm^3

24

クロム

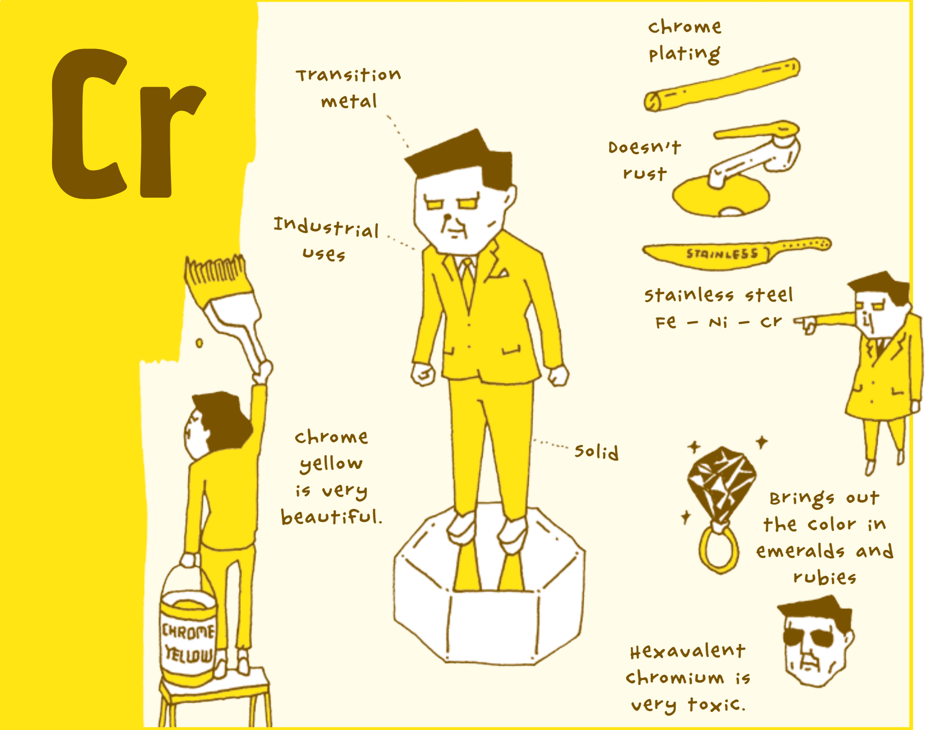
Chromium

52.00

4

6

铬



THE TORTURED ARTIST

[króumiəm]

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 ℃

BOILING POINT

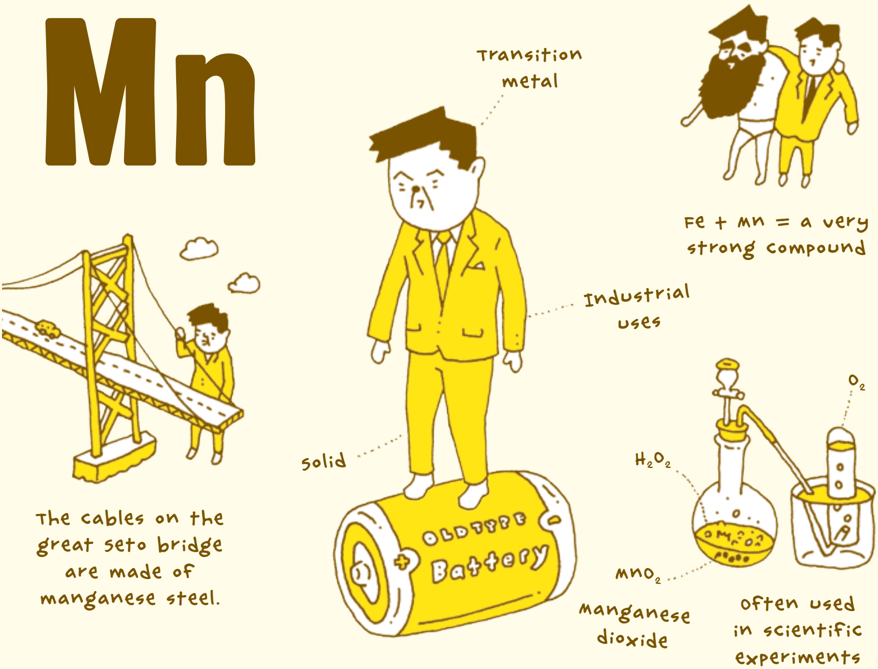
2672 ℃

DENSITY

7.19 g/cm³

25	マンガン Manganese	54.94	4 — 7	錳

Mn



A WORKER OF OLD, THE UNSUNG HERO OF THE ELEMENTS

【mǽŋgəníːs】

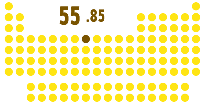
DISCOVERY YEAR: 1774

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.

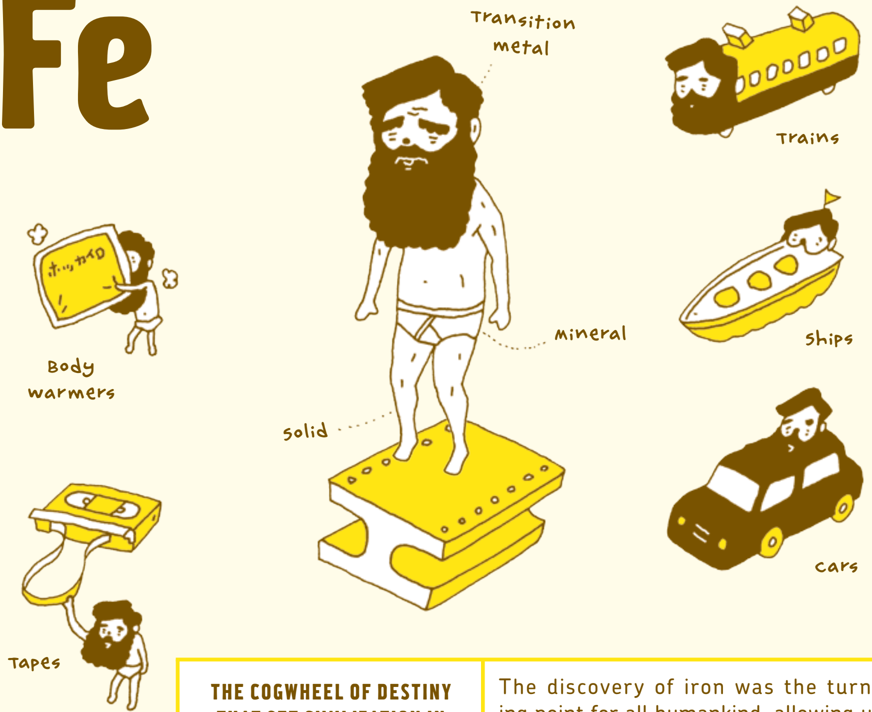
MELTING POINT	1244 ℃
BOILING POINT	1962 ℃
DENSITY	7.44 g/cm³


Get the lead out!
Not a chance. Iron's up next.
Time for a bathroom break?

26	鉄 Iron	55.85	4 / 8	铁



Fe

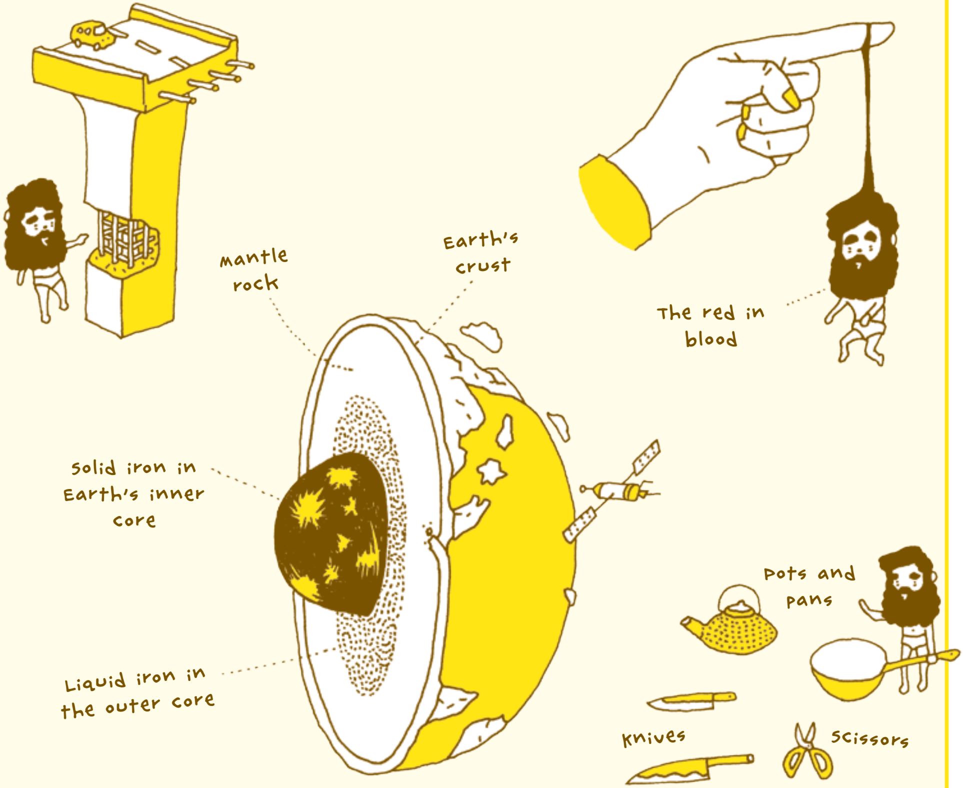


THE COGWHEEL OF DESTINY THAT SET CIVILIZATION IN MOTION

[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

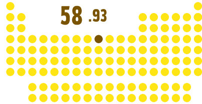


roughly 90% of the world's total metal production, and since it is incredibly abundant, easy to work with, strong, and cheap, it will probably continue to be a recipe for success far into the future. We are even more fundamentally dependent on iron, though, as the hemoglobin that carries oxygen in our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

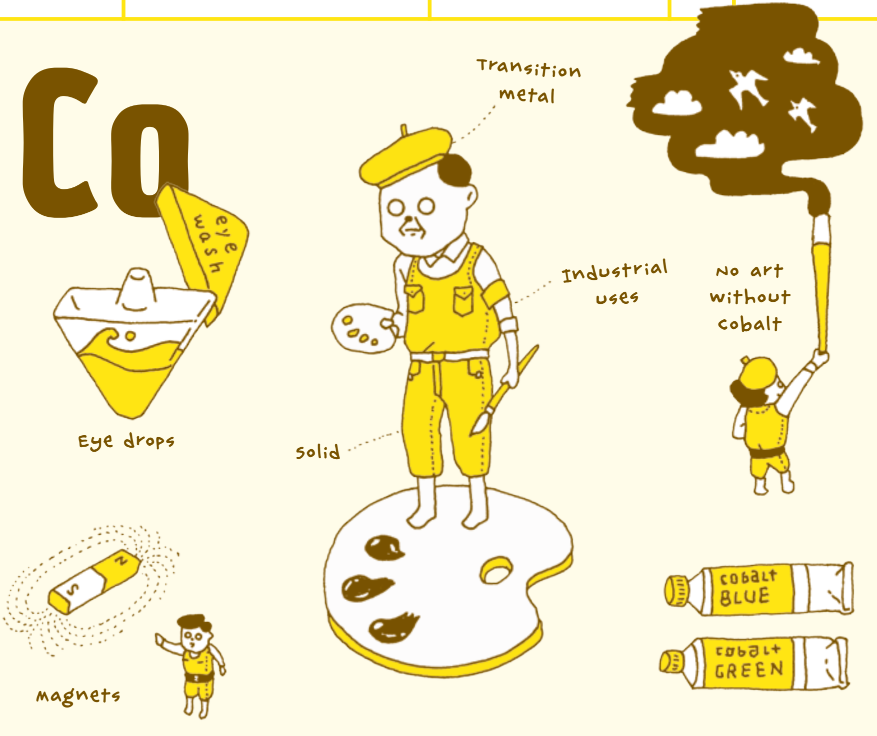
MELTING POINT	1535 ℃
BOILING POINT	2750 ℃
DENSITY	7.874 g/cm^3

There are just so many things made of iron.

27	コバルト Cobalt	58.93	4 / 9	钴



Co



THE BLUE-CLAD DIGITAL TECHNICIAN

【kóubɔːlt】

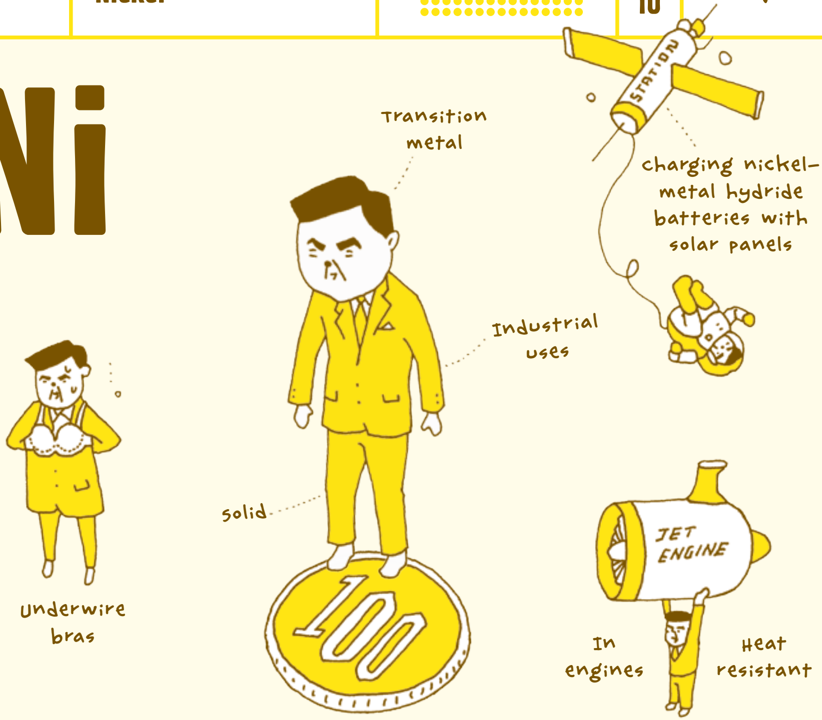
DISCOVERY YEAR: 1737

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 ℃
BOILING POINT	2870 ℃
DENSITY	8.9 g/cm³

28	ニッケル Nickel	58.69	4 10	鎳

Ni



THE MONEY MAKER

[níkəl]

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 ℃

BOILING POINT
2890 ℃

DENSITY
8.902 (25℃) g/cm³

29	銅 Copper	63.55	4 / 11	铜

Cu

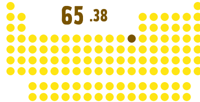
THE METAL WE'VE CARED FOR THE LONGEST

【kápər】

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 ℃
BOILING POINT	2567 ℃
DENSITY	8.96 g/cm^3

30	亜鉛 Zinc		4 12	锌

Zn

THE PICKY GOURMET ELEMENT

[zíŋk]

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 ℃
BOILING POINT	907 ℃
DENSITY	7.133 g/cm³

31	ガリウム Gallium	69.72	4 13	镓

Ga

THE KIND, NERDY ELEMENT

[gǽliəm]

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.

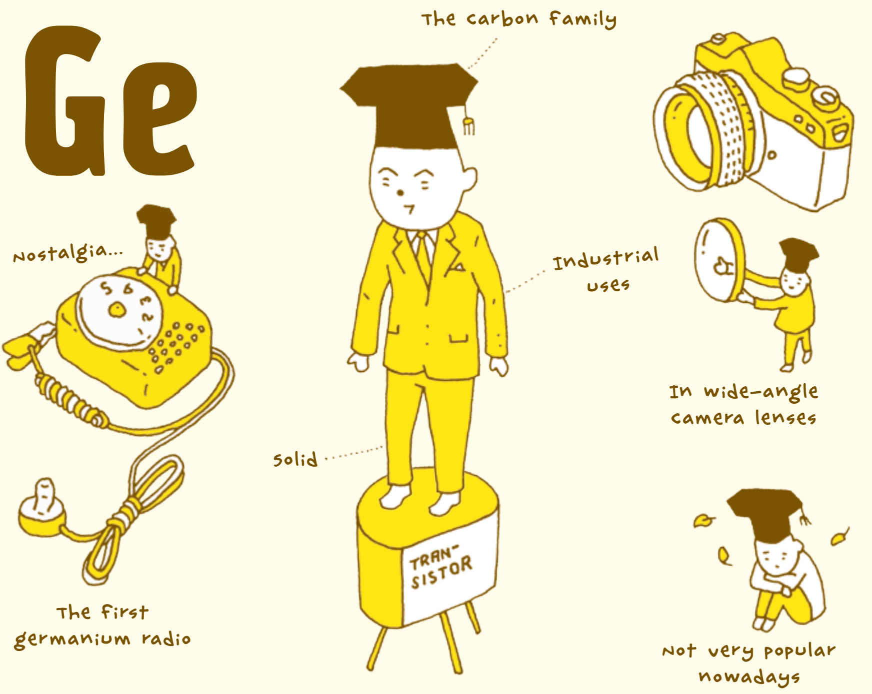
MELTING POINT 29.78 ℃

BOILING POINT 2403 ℃

DENSITY 5.907 g/cm³

32	ゲルマニウム Germanium	72.64	4 / 14	锗

Ge



THE ELEMENT FROM THE GOOD OLD DAYS

[dʒərméiniəm]

DISCOVERY YEAR: 1885

This element might be familiar to the audiophiles 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 ℃

BOILING POINT 2830 ℃

DENSITY 5.323 g/cm³

33	ヒ素 Arsenic	74.92	4 / 15	砷

As

THE RUTHLESS DARK-SIDE ELEMENT

【á:rsənik】

DISCOVERY YEAR: MEDIEVAL

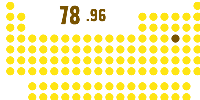
Most people probably know arsenic as a poison, rumored to be responsible for the deaths of Napoleon Bonaparte and King George III. It blocks enzymes when introduced to the bloodstream, and it is both odorless and tasteless, which makes it very hard to detect when hidden in food. Some types of seaweed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

MELTING POINT
817 (METAL, PRESSURIZED) ℃

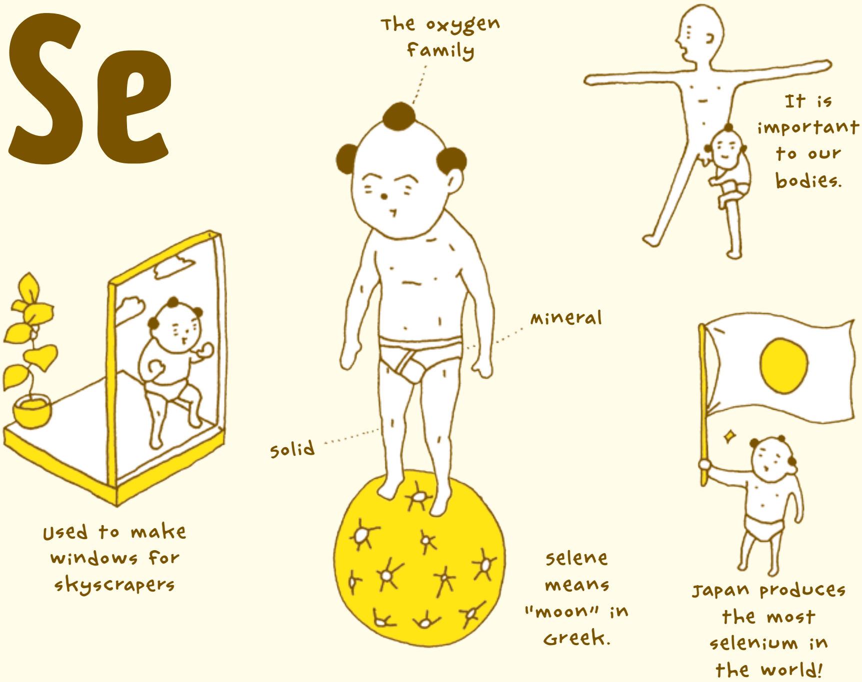
BOILING POINT
616 (SUBLIMATION) ℃

DENSITY
5.78 (METAL) g/cm³

34	セレン Selenium	78.96	4 16	硒



Se



GOOD AND EVIL, THE ELEMENT WITH TWO FACES

【silí:niəm】

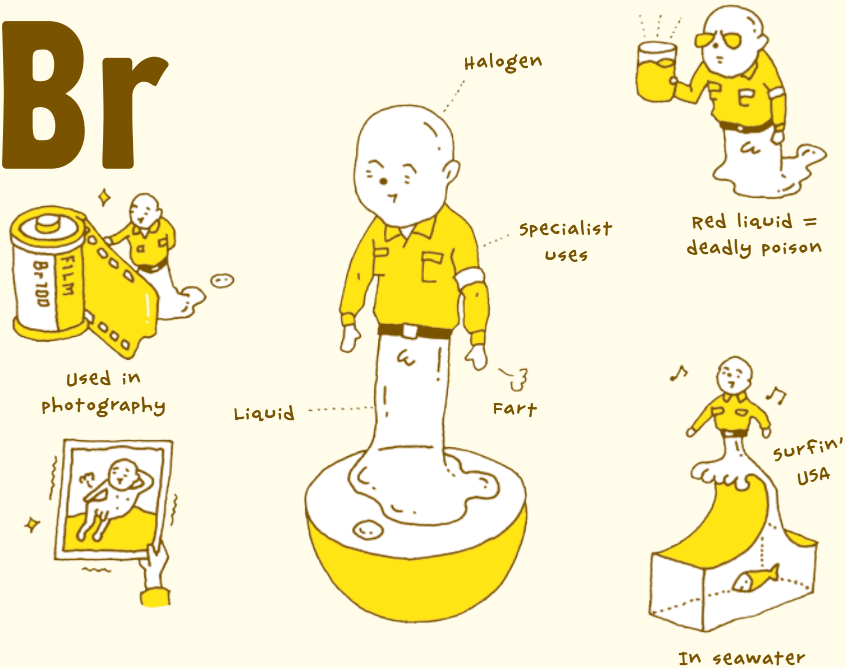
DISCOVERY YEAR: 1817

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 ℃
BOILING POINT	684.9 ℃
DENSITY	4.79 (GRAY SOLID) g/cm^3

35	臭素 Bromine	79.90	4 / 17	溴

Br



MORE ROMANTIC THAN IT SOUNDS

[bróumiːn]

DISCOVERY YEAR: 1826

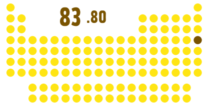
The French chemist Antoine Jérôme Balard and the German chemist Carl Jacob Löwig each independently discovered bromine as students in 1826. Bromine dyes (extracted from certain species of snails) were sought after in ancient Japan and Europe for their beautiful color, a vivid purple. Silver bromide is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

MELTING POINT
-7.3 ℃

BOILING POINT
58.78 ℃

DENSITY
3.1226 (LIQUID, 20°C) g/cm³

36	クリプトン Krypton	83.80	4 18	氪



Kr

THE BRIGHTLY SHINING FLASH-MAN

【kríptan】

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
℃

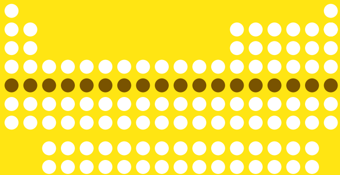
BOILING POINT
-152.3
℃

DENSITY
0.0037493
(GAS FORM, 20°C)
g/cm^3

周期

PERIOD

5



原子番号

ATOMIC NUMBER

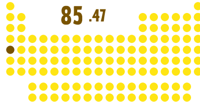
37→54


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
TC
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

Rubidium



5

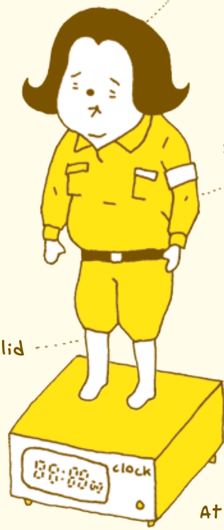
1

铷

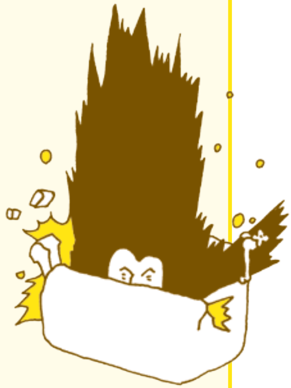
Rb

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:bídiəm】

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 ℃

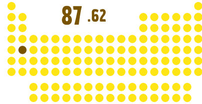
BOILING POINT

688 ℃

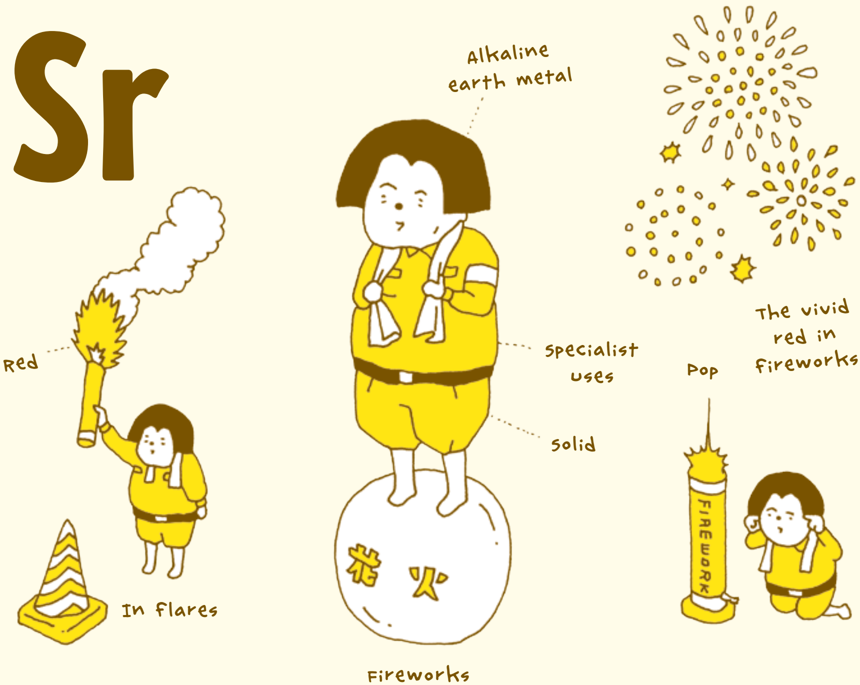
DENSITY

1.532 g/cm^3

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

38	ストロンチウム **Strontium**		5 — 2	锶

Sr



THE SWEET FIREBALL DUDE

[stránʃiəm]

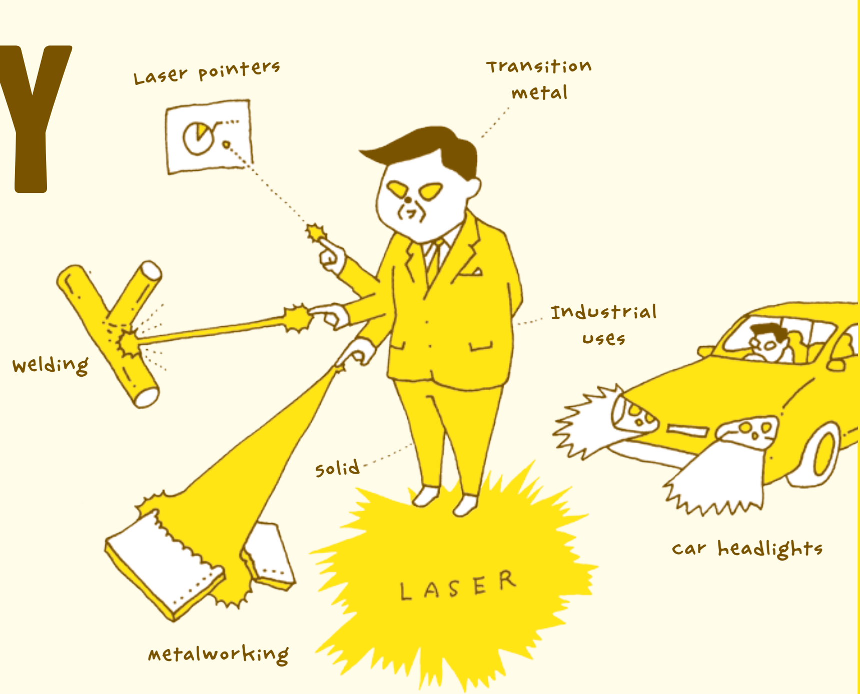
DISCOVERY YEAR: 1787

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 ℃
BOILING POINT	1384 ℃
DENSITY	2.54 g/cm^3

39	イットリウム Yttrium	88.91	5 / 3	钇

Y



THE PIONEER OF THE LASER WORLD

【ítriəm】

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.

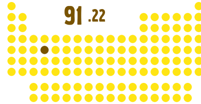
MELTING POINT
1522 ℃

BOILING POINT
3338 ℃

DENSITY
4.469 g/cm^3

40

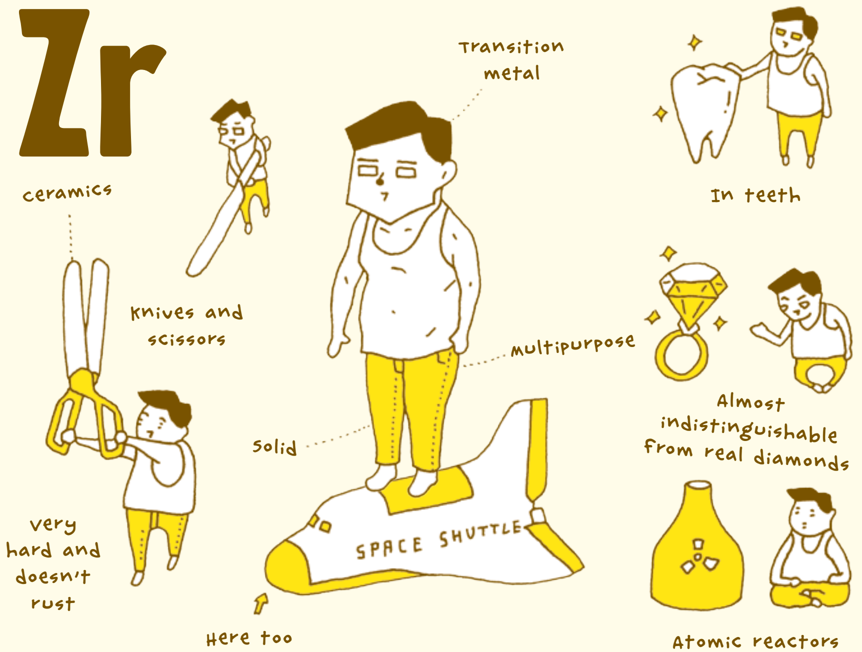
ジルコニウム
Zirconium



5
—
4

锆

Zr



DIAMONDS FOR EVERYONE!

[zəːrkóuniəm]

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 ℃

BOILING POINT
4377 ℃

DENSITY
6.506 g/cm³

41

ニオブ

Niobium

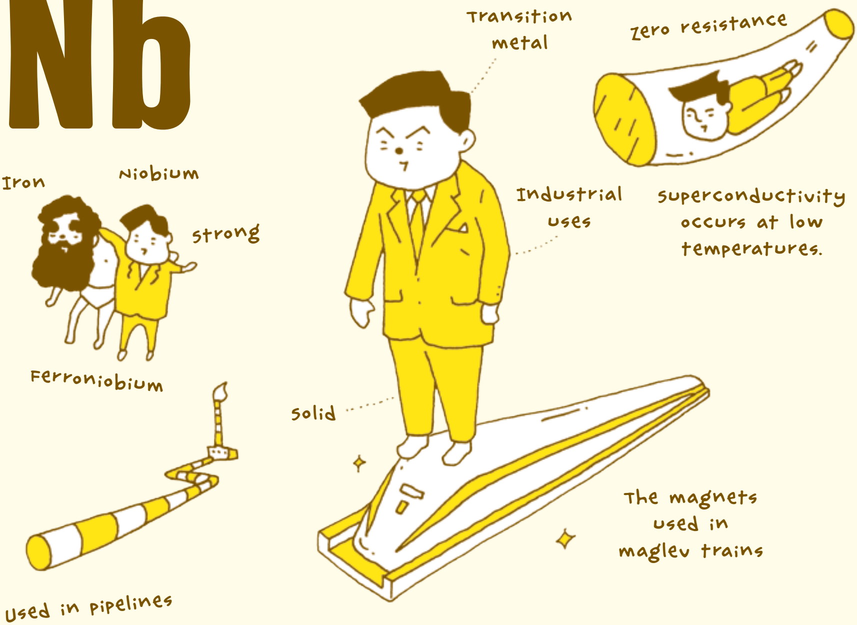
92.91

5

5

鈮

Nb



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 ℃

BOILING POINT

4742 ℃

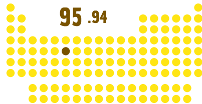
DENSITY

8.57 g/cm³

42

モリブデン

Molybdenum

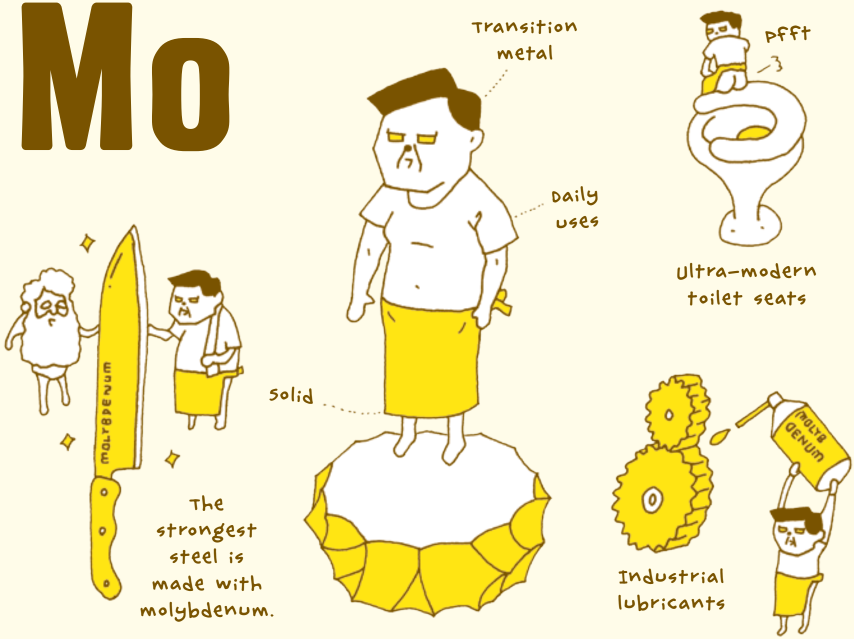


5

6

钼

Mo



THE DIVERSE BLACKSMITH

[məlíbdənəm]

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 ℃

BOILING POINT

4612 ℃

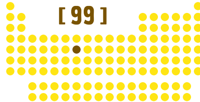
DENSITY

10.22 g/cm³

43

テクネチウム

Technetium

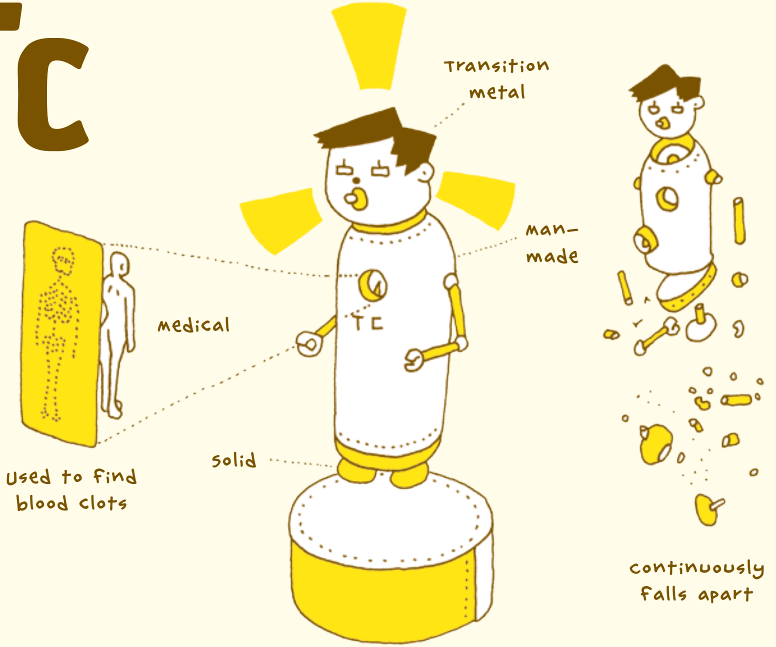


5

7

锝

Tc



THE FIRST MAN-MADE ELEMENT

【tekníːʃiəm】

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 ℃

BOILING POINT

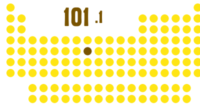
4877 ℃

DENSITY

11.5 g/cm^3

44

ルテニウム
Ruthenium

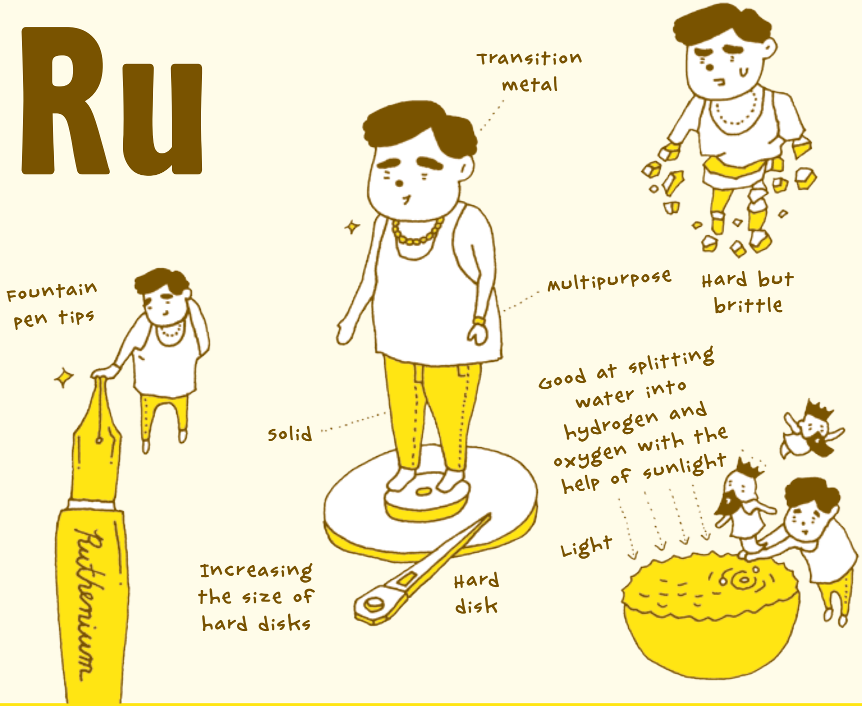


5

8

钌

Ru



A CELEBRITY SINCE BIRTH

【ru:θí: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.

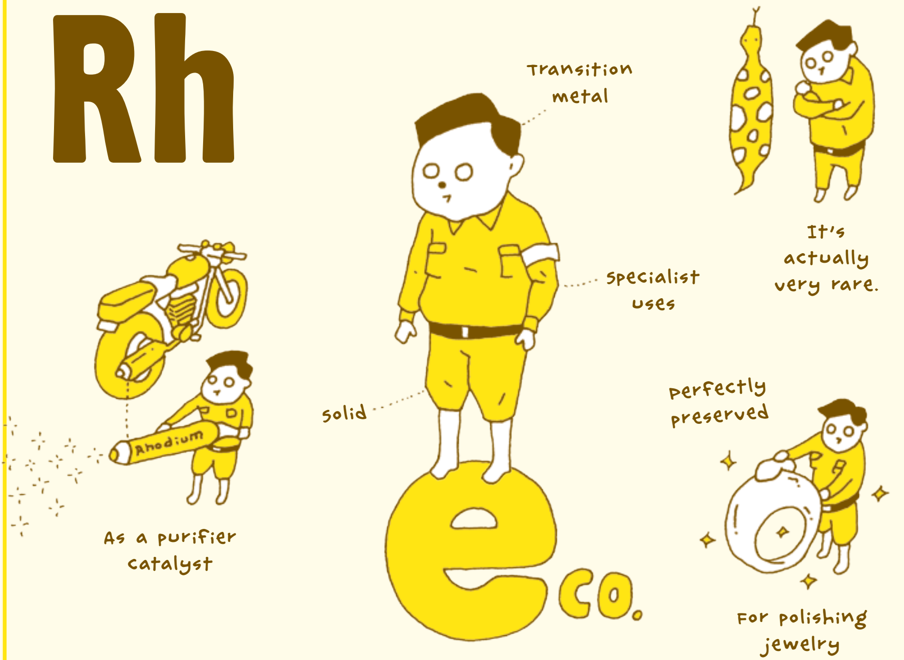
MELTING POINT
2310 ℃

BOILING POINT
3900 ℃

DENSITY
12.37 g/cm^3

45	ロジウム Rhodium	102.9	5 / 9	铑

Rh



ALWAYS 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 ℃

BOILING POINT 3727 ℃

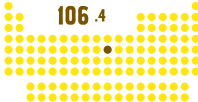
DENSITY 12.41 g/cm^3

46

パラジウム

Palladium

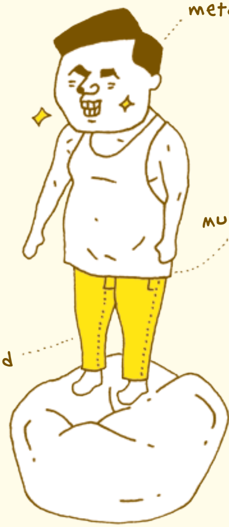
106.4



5 / 10

钯

Pd



THE FORMER UGLY DUCKLING

【pəléidiəm】

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 ℃

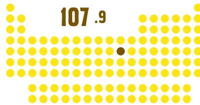
BOILING POINT
3140 ℃

DENSITY
12.02 g/cm³

47

銀

Silver



5

11

银

STYLISH AND GOOD AT WHAT HE DOES

[sílvər]

DISCOVERY YEAR: ANCIENT

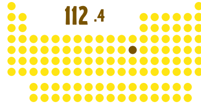
Silver's shine evokes a romantic mood, and this metal is cheap and easy to work with. This makes it perfect for utensils and accessories. Silver ions are also particularly good at killing bacteria by destabilizing their enzymes, and silver's gaining ground as a component of deodorants and odor-resistant 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 ℃

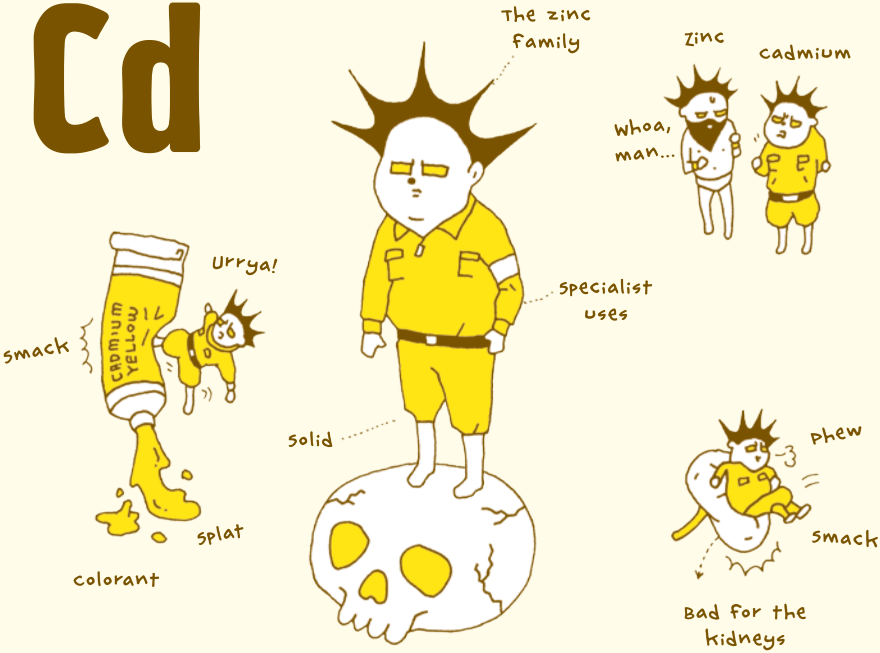
BOILING POINT
2212 ℃

DENSITY
10.5 g/cm^3

48	カドミウム Cadmium	112.4	5 — 12	镉



Cd



THE RAMPAGING MAD SCIENTIST

【kǽdmiəm】

DISCOVERY YEAR: 1817

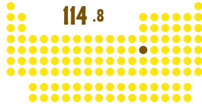
A mysterious sickness that spread near the Jinzuu River from 1912 to 1946 became known as one of the four big pollution diseases of Japan and was called the *itai-itai* ("ouch-ouch") disease. It was caused by cadmium from a mine upstream. Since it's very similar in structure to zinc, cadmium can enter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

MELTING POINT
320.9 ℃

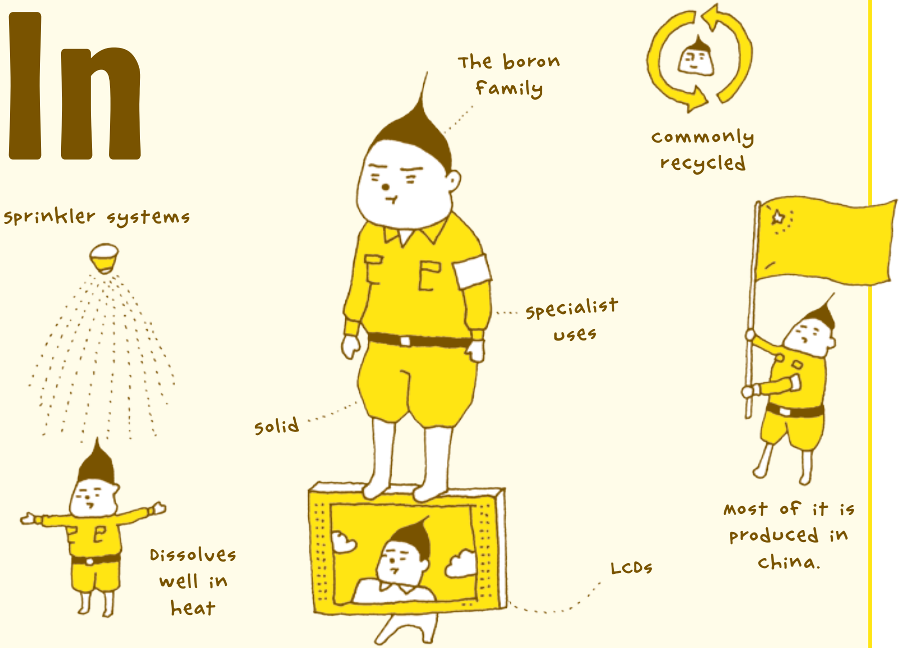
BOILING POINT
765 ℃

DENSITY
0.00865 (25°C) g/cm^3

49	インジウム Indium	114.8	5 13	铟



In



HE'S IN SEASON! THE HERO OF THE DAY

[índiəm]

DISCOVERY YEAR: 1863

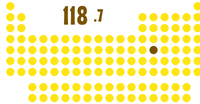
Indium is indispensable to electronics manufacturers, as it's used for making flat-screen TVs. Its unusual quality of being able to create transparent and conductive films is vital for making all types of LCD, plasma, and OLED* displays. Japan was once the world's largest producer of indium, but since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

MELTING POINT	156.17 ℃
BOILING POINT	2080 ℃
DENSITY	7.31 (25°C) g/cm³

* OLED is a type of light-emitting diode made up of organic compounds.

50 スズ Tin

118.7



5 / 14

錫

Sn

THE HERO OF OLD TURNED SLACKER

[tín]

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 ℃

BOILING POINT
2270 ℃

DENSITY
7.31 (WHITE TIN) g/cm³

51	アンチモン Antimony	121.8	5 15	锑

Sb

CLEOPATRA'S DARLING

[ǽntəmòuni]

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 ℃
BOILING POINT	1635 ℃
DENSITY	6.691 g/cm^3

52

テルル

Tellurium

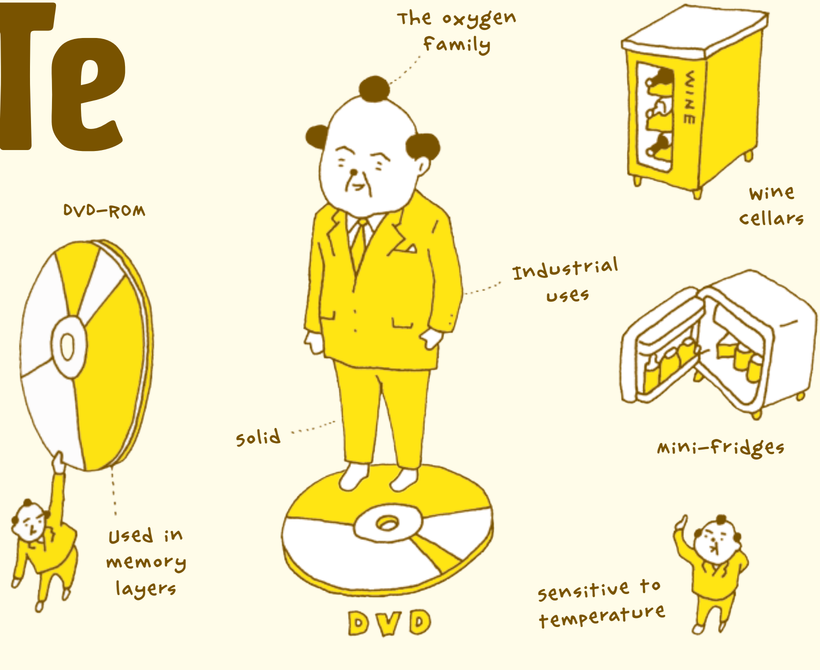
127.6

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 ℃
BOILING POINT	990 ℃
DENSITY	6.24 g/cm³

53

ヨウ素
Iodine

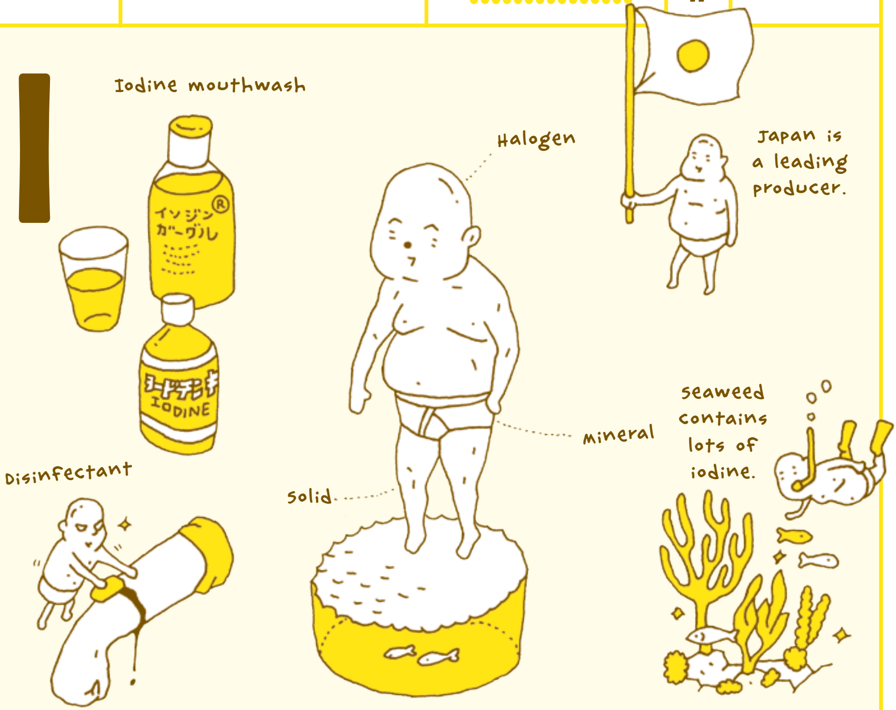
126.9

5

17

碘

I



BORN FROM SEAWEED AND RAISED IN THE CHIBA PREFECTURE

【áiədàin】

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 ℃

BOILING POINT
184.4 ℃

DENSITY
4.93 g/cm^3

54

キセノン

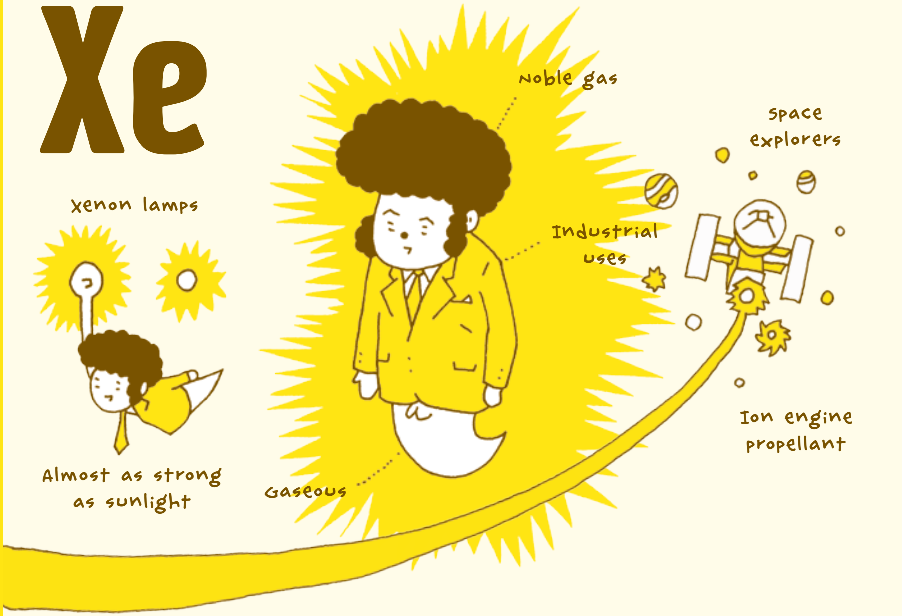
Xenon

131.3

5 / 18

氙

Xe



THE RISING GAS THAT TRAVELS AMONG THE STARS

[zí: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 ℃

BOILING POINT

-107.1 ℃

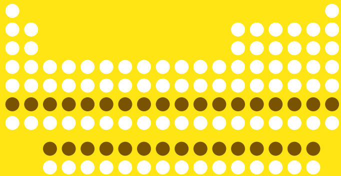
DENSITY

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
プラセオジム
Praseodymium
60
ネオジム
Neodymium
61
プロメチウム
Promethium
62
サマリウム
Samarium
63
ユウロピウム
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 Cesium	132.9	6 / 1	铯

Cs

SECOND TO NONE

[sí:ziəm]

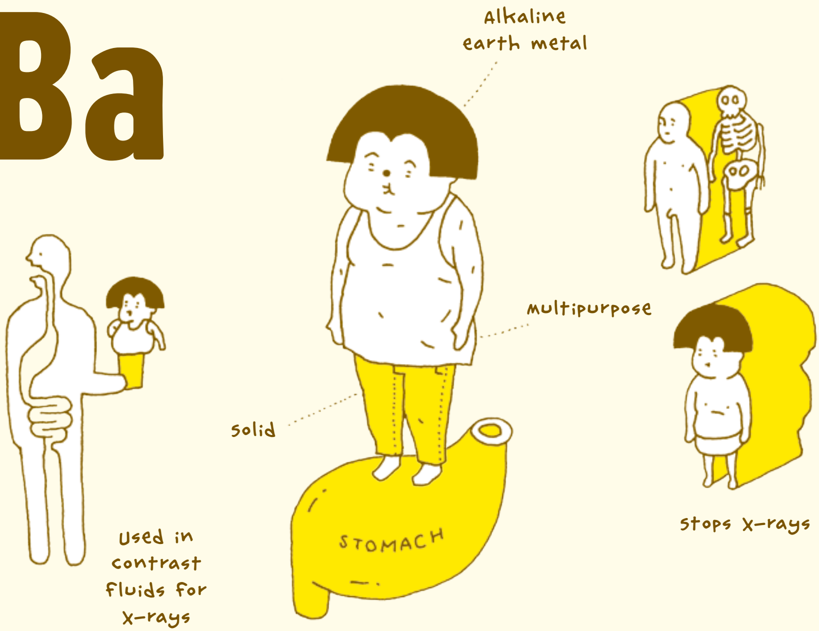
DISCOVERY YEAR: 1860

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 ℃
BOILING POINT	668.5 ℃
DENSITY	1.873 g/cm^3

56	バリウム Barium	137.3	6 / 2	钡

Ba



A DOCTOR AT WORK, A GANGSTER AT HOME

[bέəriəm]

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 ℃

BOILING POINT 1637 ℃

DENSITY 3.594 g/cm³

57	ランタン Lanthanum	138.9	6 / 3	鑭

La

THE LEADER OF THE OUTSIDERS

【lǽnθənəm】

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 ℃

BOILING POINT
3457 ℃

DENSITY
6.145 (25°C) g/cm³

58 セリウム Cerium

[síəriəm]

DISCOVERY YEAR: 1803

Ce

THE MAINSTAY OF THE LANTHANIDES

铈

140.1

6	MELTING POINT 799 ℃
3	BOILING POINT 3426 ℃
	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 プラセオジム Praseodymium

[prèizioudímiəm]

DISCOVERY YEAR: 1885

Pr

THE FLAMING YELLOW MAGICIAN

镨

140.9

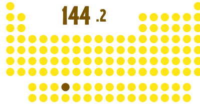
6	MELTING POINT 931 ℃
3	BOILING POINT 3512 ℃
	DENSITY 6.773 g/cm³

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

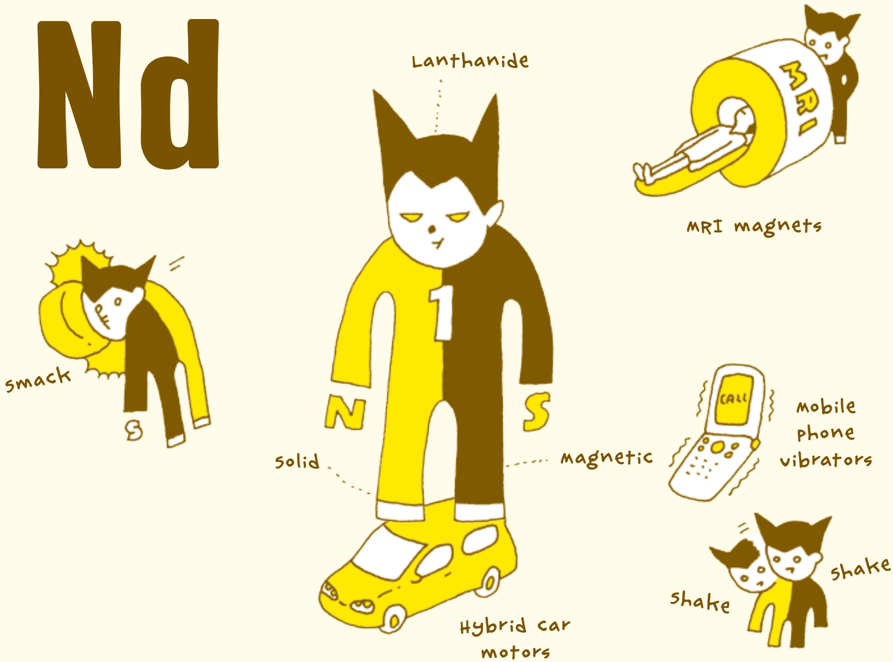


6

3

钕

Nd



THE WORLD'S STRONGEST SUPER MAGNET

【ní:oudímiəm】

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 ℃

BOILING POINT
3068 ℃

DENSITY
7.007 g/cm^3

61 プロメチウム Promethium

【prəmí:θiəm】

DISCOVERY YEAR: 1926

Pm

THE FIERY CHILD BORN IN OUR REACTORS

钜

[145]	6	MELTING POINT 1168 ℃
		BOILING POINT APPROX. 2727 ℃
	3	DENSITY 7.22 g/cm^3

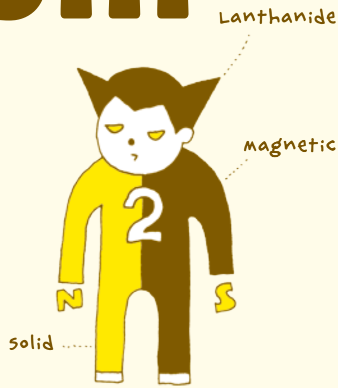
The only man-made radioactive lanthanide element is named after the Titan who gave humanity fire: Prometheus. Born in our atomic reactors, it produces heat that's perfect for powering nuclear cells.

62 サマリウム Samarium

【səméəriəm】

DISCOVERY YEAR: 1879

Sm



NUMBER TWO IN THE WORLD OF MAGNETISM

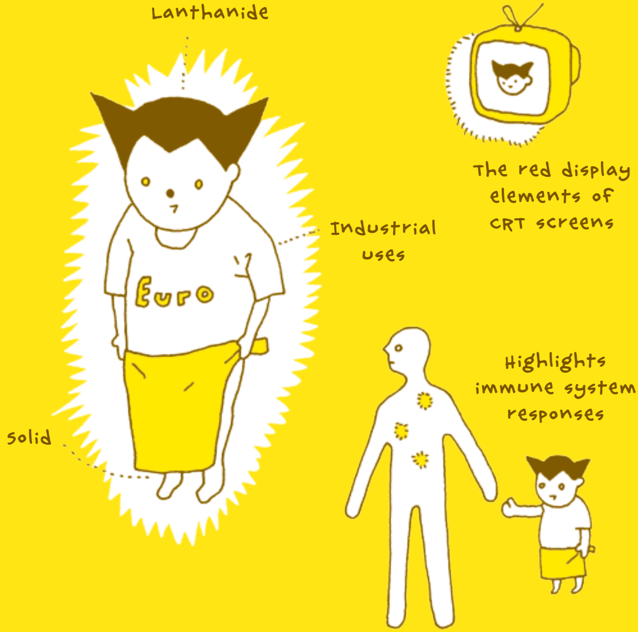
钐

150.4	6	MELTING POINT 1077 ℃
		BOILING POINT 1791 ℃
	3	DENSITY 7.52 g/cm^3

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	152.0	6 / 3	铕

Eu



A RESIDENT OF THE NIGHT, LIGHTING UP THE DARK

【juəróupiəm】

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.

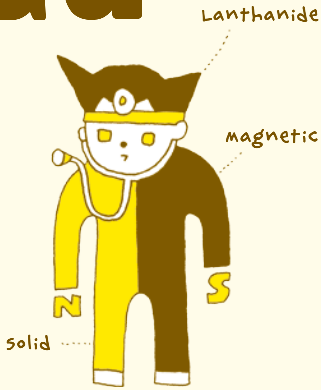
MELTING POINT	822 ℃
BOILING POINT	1597 ℃
DENSITY	5.243 g/cm^3

64 ガドリニウム Gadolinium

Gd

【gædəlíniəm】

DISCOVERY YEAR: 1886



FINDING ILLNESS WITH THE HELP OF MAGNETISM!

钆

157.3	6	MELTING POINT 1313 ℃
		BOILING POINT 3266 ℃
	3	DENSITY (25°C) 7.9004 g/cm³

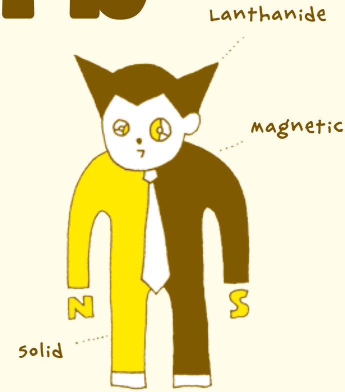
Gadolinium is a component of the contrast agent used in most MRI examinations, and it's also in nuclear reactors because of its ability to absorb emitted neutrons well.

65 テルビウム Terbium

Tb

【tə́:rbiəm】

DISCOVERY YEAR: 1843



THE OVERLOOKED MAGNET OF YESTERYEAR

铽

158.9	6	MELTING POINT 1356 ℃
		BOILING POINT 3123 ℃
	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

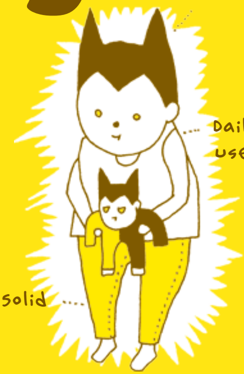
ジスプロシウム

Dysprosium

【disprόusiəm】

DISCOVERY YEAR: 1886

Dy



THE STRONGEST TAG TEAM! DYSPROSIUM AND NEODYMIUM

镝

162.5	6	MELTING POINT 1412 ℃
		BOILING POINT 2562 ℃
	3	DENSITY 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

【hóulmiəm】

DISCOVERY YEAR: 1879

Ho

A PAL TO PROSTATES EVERYWHERE

钬

164.9	6	MELTING POINT 1474 ℃
		BOILING POINT 2395 ℃
	3	DENSITY 8.795 g/cm³

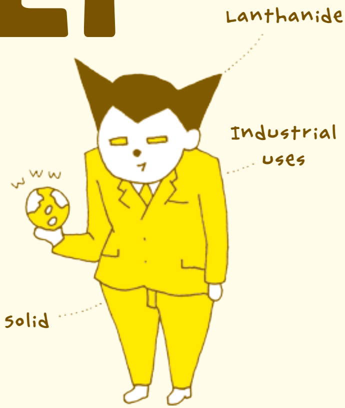
Holmium lasers are a perfect treatment method for prostatic hypertrophy. The laser prevents hemorrhage as the incision is performed. It is also great for removing renal and urethral stones.

68 エルビウム Erbium

[ə́:rbiəm]

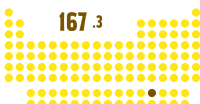
DISCOVERY YEAR: 1843

Er



MANAGING OUR WORLDWIDE NETWORKS

铒



6

3

MELTING POINT	1529 ℃
BOILING POINT	2863 ℃
DENSITY (25℃)	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

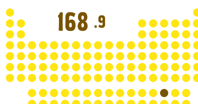
[θjú:liəm]

DISCOVERY YEAR: 1879

Tm

ERBIUM'S LITTLE BROTHER

铥



6

3

MELTING POINT	1545 ℃
BOILING POINT	1947 ℃
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

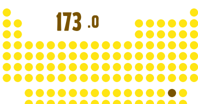
【itə́:rbiəm】

DISCOVERY YEAR: 1878

Yb

ANOTHER ONE FROM TEAM SCANDINAVIA

镱



173.0

6 / 3	
MELTING POINT	824 ℃
BOILING POINT	1193 ℃
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

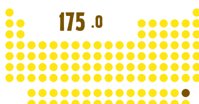
【lu:tí:ʃiəm】

DISCOVERY YEAR: 1907

Lu

MORE EXPENSIVE THAN GOLD! THE ROYAL ELEMENT

镥



175.0

6 / 3	
MELTING POINT	1663 ℃
BOILING POINT	3395 ℃
DENSITY	9.84 g/cm³

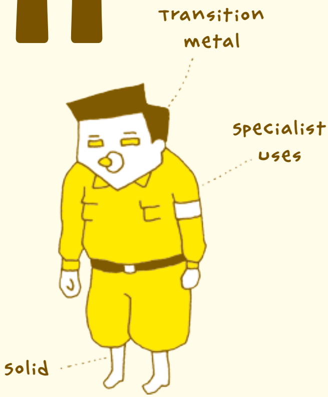
It's hard to believe, but lutetium costs a whopping ¥50,500* per gram! That's more than the price of silver, gold, and platinum combined. It doesn't really have any applications outside of research, though.

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

72	ハフニウム Hafnium

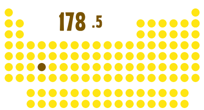
[hǽfniəm]
DISCOVERY YEAR: 1922

Hf



ZIRCONIUM'S SIGNIFICANT OTHER

鉿



6	MELTING POINT 2230 ℃
4	BOILING POINT 5197 ℃
	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.

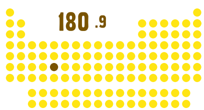
73	タンタル Tantalum

[tǽntələm]
DISCOVERY YEAR: 1802

Ta

FOR BONE PROSTHESES AND MOBILE PHONES

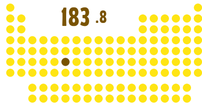
钽



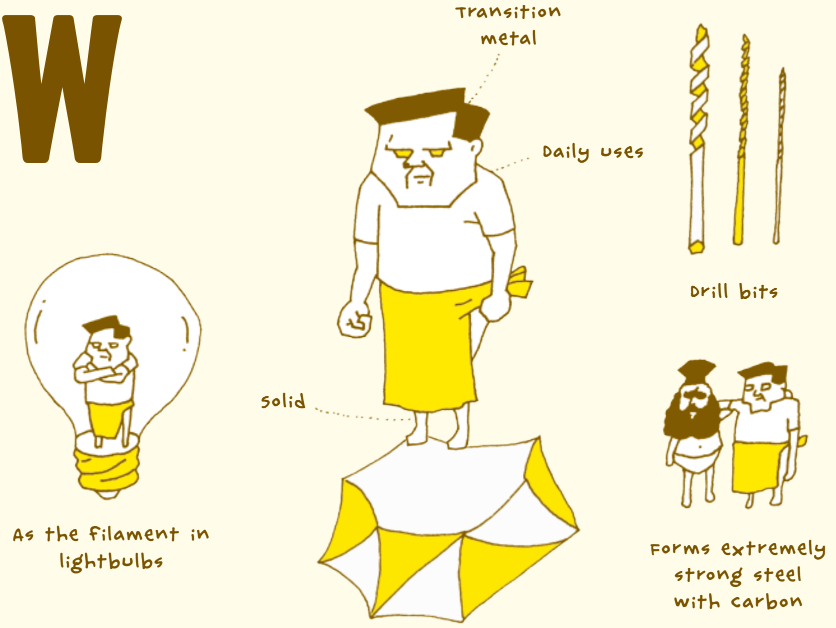
6	MELTING POINT 2996 ℃
5	BOILING POINT 5425 ℃
	DENSITY 16.654 g/cm³

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	183.8	6 / 6	钨



W



THE WORLD'S MOST THICK-SKINNED ARTISAN

[tʌ́ŋstən]

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 ℃

BOILING POINT 5657 ℃

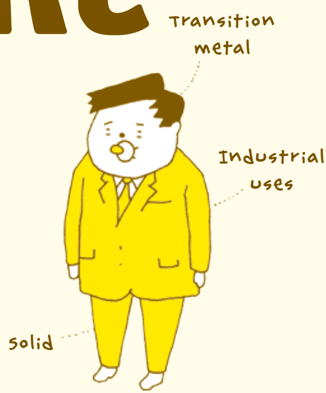
DENSITY 19.3 g/cm³

75 レニウム Rhenium

【rí:niəm】

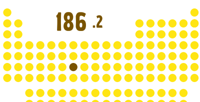
DISCOVERY YEAR: 1925

Re



OUR MOST RECENT NATURAL FIND

铼



6

7

MELTING POINT	3180 ℃
BOILING POINT	5627 ℃
DENSITY	21.02 g/cm^3

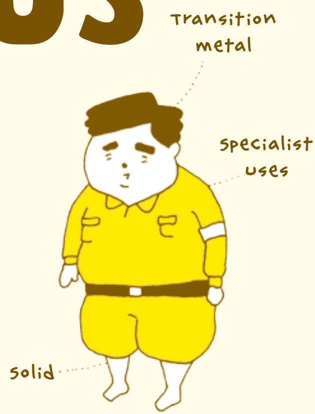
Rhenium is our most recent natural find. It has the second-highest melting point, just below that of tungsten. This makes it ideal for high-temperature measuring equipment and rocket nozzles.

76 オスミウム Osmium

【ázmiəm】

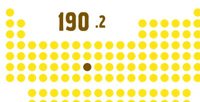
DISCOVERY YEAR: 1803

Os



THE HEAVIEST SUMO OF THEM ALL

锇



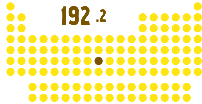
6

8

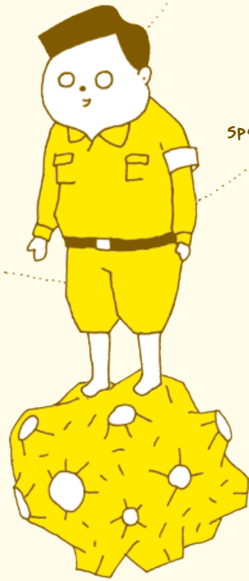
MELTING POINT	3054 ℃
BOILING POINT	5027 ℃
DENSITY	22.59 g/cm^3

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.

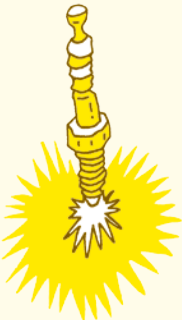
77	イリジウム Iridium	192.2	6 — 9	铱



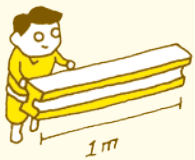
Ir



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



Spark plugs are made of iridium alloys.



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

THE ELEMENT CLOSEST TO ETERNITY

[irídiəm]

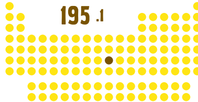
DISCOVERY YEAR: 1803

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.

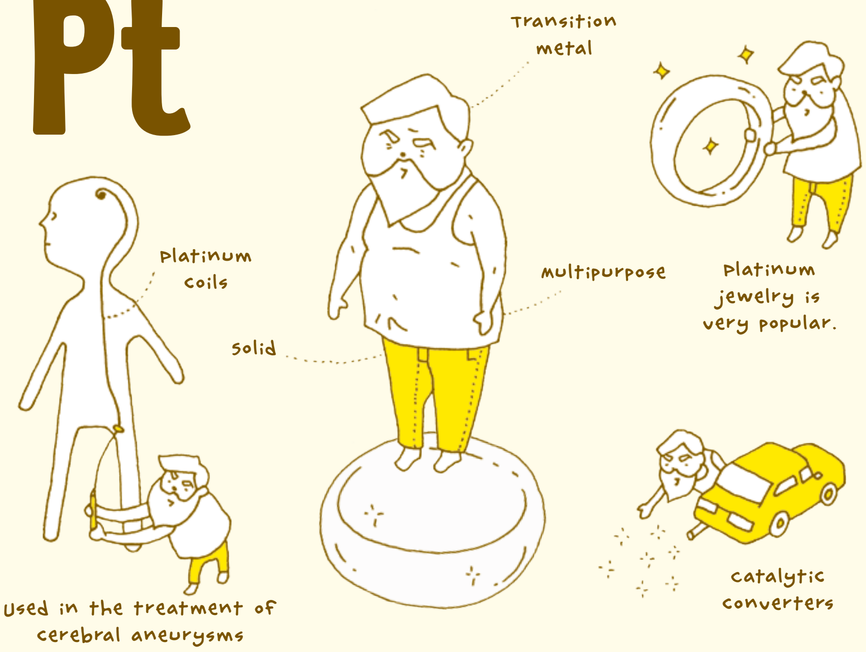
MELTING POINT
2410 ℃

BOILING POINT
4130 ℃

DENSITY
22.56 g/cm^3

78	**白金（プラチナ）** **Platinum**		**6** **10**	**铂**

Pt



THE LATE-BLOOMING STAR

[plǽtənəm]

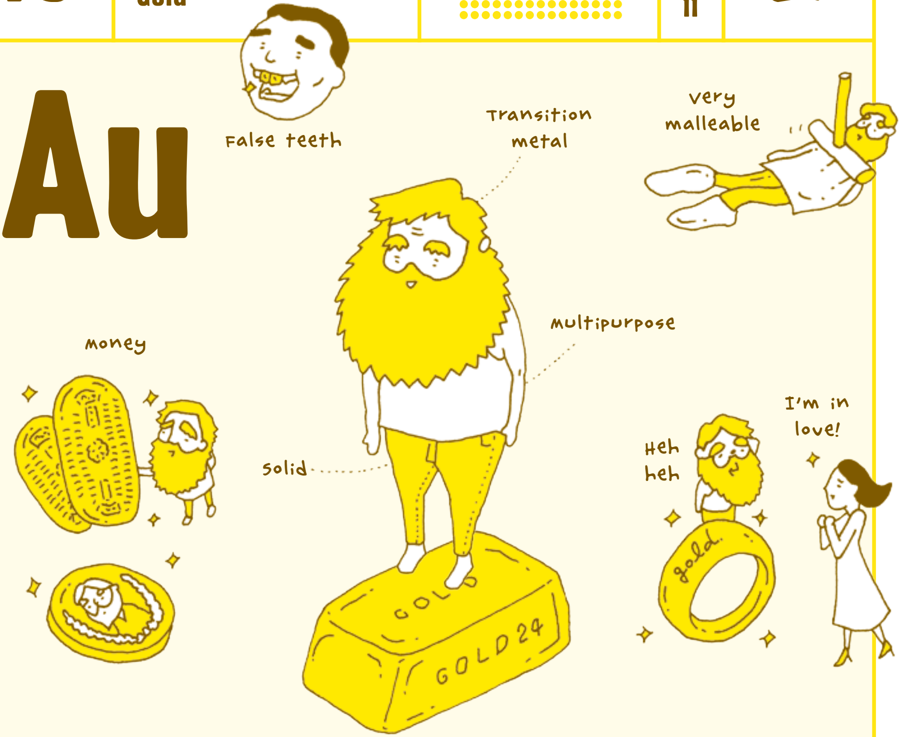
DISCOVERY YEAR: 1751

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 ℃
BOILING POINT	3827 ℃
DENSITY	21.45 g/cm^3

79	金 Gold	197.0	6 / 11	金

Au



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 ℃

BOILING POINT 2807 ℃

DENSITY 19.32 g/cm^3

80	水銀 Mercury	200.6	6 — 12	汞

Hg

THE MUTANT OF THE METAL WORLD

[mé: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 ℃

BOILING POINT
356.58 ℃

DENSITY
13.546 (LIQUID, 20°C) g/cm³

81

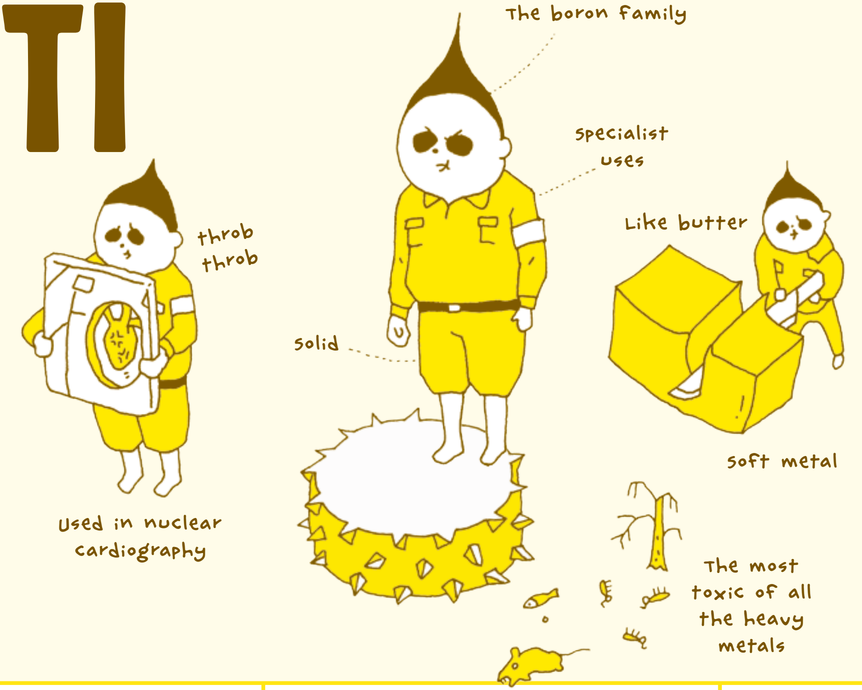
タリウム
Thallium

204.4

6
13

鉈

Tl



WITH THE UNEXPECTED ABILITY TO DETECT HEART ATTACKS

[θǽliəm]

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 ℃

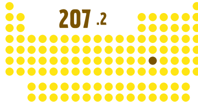
BOILING POINT
1457 ℃

DENSITY
11.85 g/cm³

82

鉛

Lead



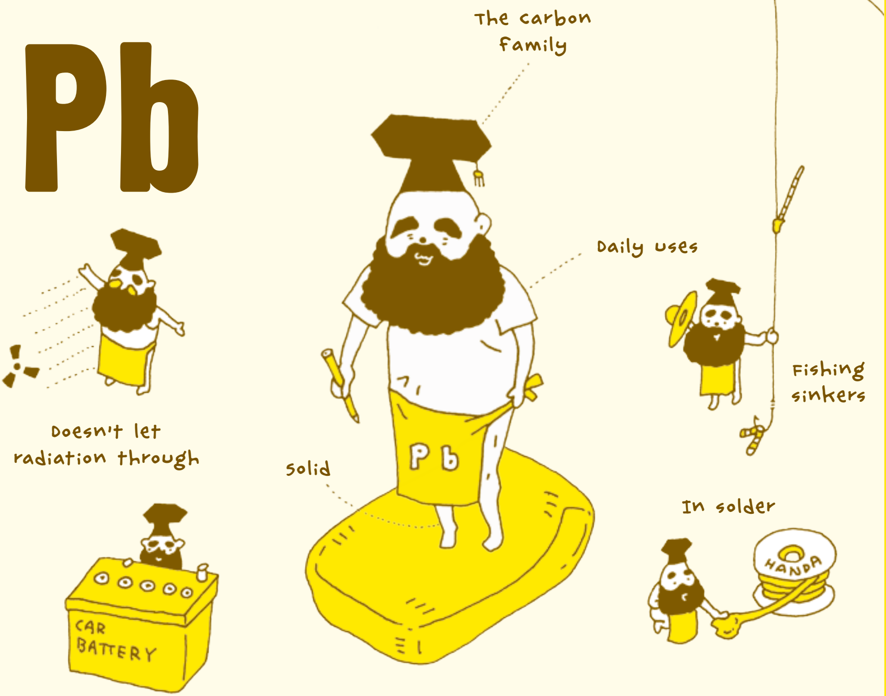
207.2

6

14

鉛

Pb



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 ℃

BOILING POINT

1740 ℃

DENSITY

11.35 g/cm³

83 ビスマス Bismuth

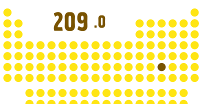
【bízməθ】

DISCOVERY YEAR: 1753

Bi

LEAD'S FAITHFUL SUCCESSOR

鉍



209.0	6	MELTING POINT	271.3 ℃
	15	BOILING POINT	1560 ℃
		DENSITY	9.747 g/cm^3

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

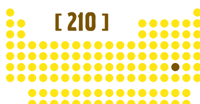
【pəlóuniəm】

DISCOVERY YEAR: 1898

Po

THE MOST DESTRUCTIVE OF THE NATURAL ELEMENTS

钋



[210]	6	MELTING POINT	254 ℃
	16	BOILING POINT	962 ℃
		DENSITY	9.32 g/cm^3

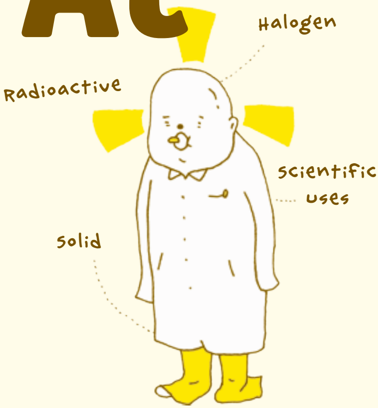
The naturally radioactive element polonium was the first element to be discovered by the Curies, with a radioactive intensity about 330 times as strong as that of uranium.

85 アスタチン Astatine

【æstətíːn】

DISCOVERY YEAR: 1940

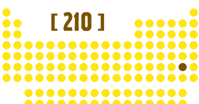
At



THE LAST SAMURAI OF THE HALOGENS

砹

[210]



6 / 17	
MELTING POINT	302 ℃
BOILING POINT	337 ℃
DENSITY	--- g/cm³

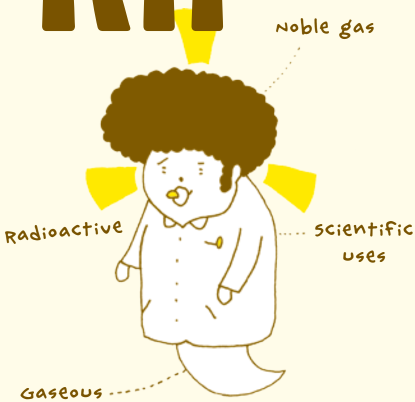
Naturally occurring astatine is the most rarely encountered element in nature and has to be synthesized in order to be studied. Determining its properties is very hard because its half-life is so short.

86 ラドン Radon

【réidɑn】

DISCOVERY YEAR: 1900

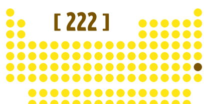
Rn



THE CHUBBY BATHING BEAUTY

氡

[222]



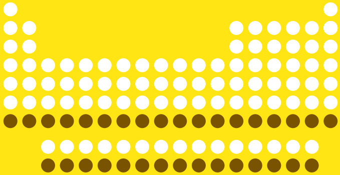
6 / 18	
MELTING POINT	-71 ℃
BOILING POINT	-61.8 ℃
DENSITY (GAS, 0°C)	0.00973 g/cm³

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

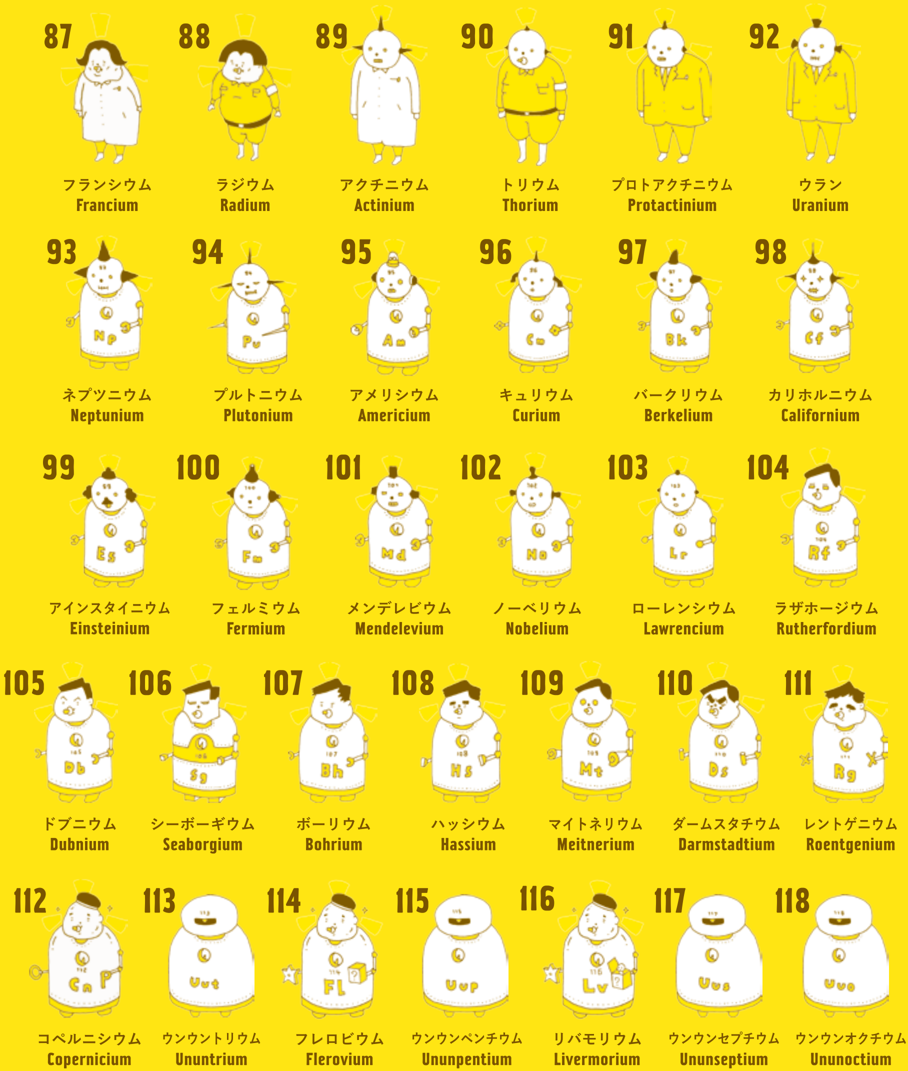
7



原子番号

ATOMIC NUMBER

87→118

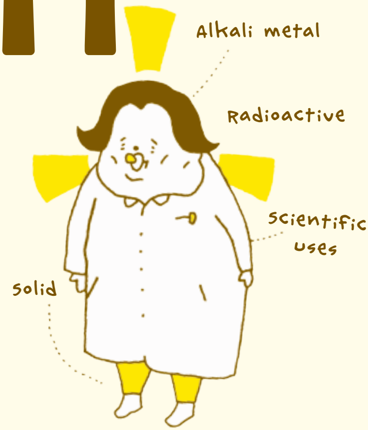

87
フランシウム
Francium
88
ラジウム
Radium
89
アクチニウム
Actinium
90
トリウム
Thorium
91
プロトアクチニウム
Protactinium
92
ウラン
Uranium
93
ネプツニウム
Neptunium
94
プルトニウム
Plutonium
95
アメリシウム
Americium
96
キュリウム
Curium
97
バークリウム
Berkelium
98
カリホルニウム
Californium
99
アインスタイニウム
Einsteinium
100
フェルミウム
Fermium
101
メンデレビウム
Mendelevium
102
ノーベリウム
Nobelium
103
ローレンシウム
Lawrencium
104
ラザホージウム
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

【frǽnsiəm】

DISCOVERY YEAR: 1939

Fr



THE FLEETING MYSTERY

钫

[223]

7	MELTING POINT 27 ℃
	BOILING POINT 677 ℃
1	DENSITY --- g/cm³

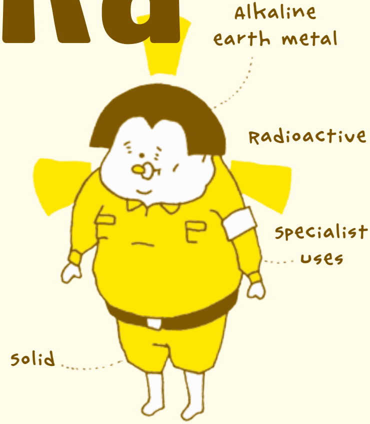
Francium has the shortest half-life of all naturally occurring radioactive elements at about 22 minutes. It is thought that the element is solid at room temperature, but that is still under debate.

88 ラジウム Radium

【réidiəm】

DISCOVERY YEAR: 1898

Ra



THE ELEMENT THAT BIT THE HAND THAT FED IT

镭

[226]

7	MELTING POINT 700 ℃
	BOILING POINT 1140 ℃
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 錒

THE FIRST ACTINIDE

[227]

7 / 3	
MELTING POINT	1047 ℃
BOILING POINT	3197 ℃
DENSITY	10.06 g/cm³

91 プロトアクチニウム Protactinium

Pa 鏷

DISCOVERED BY TWO LEGENDARY SCIENTISTS*

231.0

7 / 3	
MELTING POINT	1840 ℃
BOILING POINT	4030 ℃
DENSITY	15.37 g/cm³

* Germany's Otto Haan and Lise Meitner

90 トリウム Thorium

Th 钍

HOLDS GREAT PROMISE AS THE FUEL OF TOMORROW

232.0

7 / 3	
MELTING POINT	1750 ℃
BOILING POINT	4787 ℃
DENSITY	11.72 g/cm³

92 ウラン Uranium

U 铀

FOR NUCLEAR POWER PLANTS AND ATOMIC BOMBS

238.0

7 / 3	
MELTING POINT	1132.3 ℃
BOILING POINT	3745 ℃
DENSITY	18.95 g/cm³

93 ネプツニウム Neptunium

Np

鎿

Actinide
Radioactive
Solid
man-made

EVEN HEAVIER THAN URANIUM

[237]

7 / 3

MELTING POINT	640 ℃
BOILING POINT	3902 ℃
DENSITY	20.25 g/cm³

94 プルトニウム Plutonium

Pu

钚

Actinide
Radioactive
Solid
man-made

ATOMIC ENERGY FOR WEAPONS AND POWER

[239]

7 / 3

MELTING POINT	641 ℃
BOILING POINT	3232 ℃
DENSITY (25°C)	19.84 g/cm³

95 アメリシウム Americium

Am

镅

Actinide
Radio-active
Solid
man-made

USED IN SMOKE DETECTORS

[243]

7 / 3

MELTING POINT	1172 ℃
BOILING POINT	2607 ℃
DENSITY	13.67 g/cm³

96 キュリウム Curium

Cm

锔

Actinide
Radioactive
Solid
man-made

NAMED AFTER PIERRE AND MARIE CURIE

[247]

7 / 3

MELTING POINT	1337 ℃
BOILING POINT	3110 ℃
DENSITY	13.3 g/cm³

97 バークリウム Berkelium

Bk

鉳

Actinide
Radioactive
Solid
man-made

MADE IN THE UNIVERSITY OF CALIFORNIA, BERKELEY

[247]

7	MELTING POINT 1047 ℃
3	BOILING POINT --- ℃
	DENSITY 14.79 g/cm³

99 アインスタイニウム Einsteinium

Es

锿

Actinide
Radioactive
Solid
man-made

FOUND DURING THE HYDROGEN BOMB EXPERIMENTS

[252]

7	MELTING POINT 860 ℃
3	BOILING POINT --- ℃
	DENSITY --- g/cm³

98 カリホルニウム Californium

Cf

锎

Actinide
Radioactive
Solid
man-made

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

[252]

7	MELTING POINT 897 ℃
3	BOILING POINT --- ℃
	DENSITY 15.1 g/cm³

100 フェルミウム Fermium

Fm

镄

Actinide
Radioactive
Solid
man-made

NAMED AFTER ENRICO FERMI, WHO DEVELOPED THE FIRST ATOMIC REACTOR

[257]

7	MELTING POINT --- ℃
3	BOILING POINT --- ℃
	DENSITY --- g/cm³

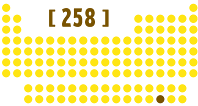
101 メンデレビウム Mendelevium

Md

鍆

Actinide
Radioactive
solid
man-made

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



[258]

7 / 3

MELTING POINT	--- ℃
BOILING POINT	--- ℃
DENSITY	--- g/cm³

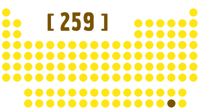
102 ノーベリウム Nobelium

No

鍩

Actinide
Radioactive
solid
man-made

NAMED AFTER THE HONORABLE ALFRED NOBEL



[259]

7 / 3

MELTING POINT	--- ℃
BOILING POINT	--- ℃
DENSITY	--- g/cm³

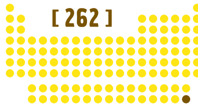
103 ローレンシウム Lawrencium

Lr

鐒

Actinide
Radioactive
solid
man-made

NAMED AFTER ERNEST LAWRENCE, THE PHYSICIST



[262]

7 / 3

MELTING POINT	--- ℃
BOILING POINT	--- ℃
DENSITY	--- g/cm³

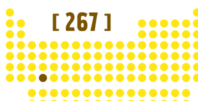
104 ラザホージウム Rutherfordium

Rf

鑪

Transition metal
Radioactive
solid
man-made

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



[267]

7 / 4

MELTING POINT	--- ℃
BOILING POINT	--- ℃
DENSITY	23 g/cm³

105 ドブニウム Dubnium

Db 𬭊

Transition metal
Radioactive
Solid
man-made

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

[268]

7	MELTING POINT --- ℃
5	BOILING POINT --- ℃
	DENSITY 29 g/cm³

106 シーボーギウム Seaborgium

Sg 𬭳

Transition metal
Radioactive
Solid
man-made

NAMED AFTER GLENN SEABORG, WHO DISCOVERED TEN ELEMENTS

[271]

7	MELTING POINT --- ℃
6	BOILING POINT --- ℃
	DENSITY 35 g/cm³

107 ボーリウム Bohrium

Bh 𬭛

Transition metal
Radioactive
Solid
man-made

NAMED AFTER THE DANISH PHYSICIST NIELS BOHR

[272]

7	MELTING POINT --- ℃
7	BOILING POINT --- ℃
	DENSITY 37 g/cm³

108 ハッシウム Hassium

Hs 𬭶

Transition metal
Radioactive
Solid
man-made

NAMED AFTER ITS PLACE OF DISCOVERY, HESSE IN GERMANY

[277]

7	MELTING POINT --- ℃
8	BOILING POINT --- ℃
	DENSITY 41 g/cm³

109 マイトネリウム Meitnerium

Mt 鿏

Transition metal
Radioactive
Solid
man-made

NAMED AFTER THE FEMALE AUSTRIAN PHYSICIST, LISE MEITNER

[276]

7	MELTING POINT	--- ℃
9	BOILING POINT	--- ℃
	DENSITY	--- g/cm³

111 レントゲニウム Roentgenium

Rg 𬬭

Transition metal
Radioactive
Solid
man-made

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

[280]

7	MELTING POINT	--- ℃
11	BOILING POINT	--- ℃
	DENSITY	--- g/cm³

110 ダームスタチウム Darmstadtium

Ds 鐽

Transition metal
Radioactive
Solid
man-made

NAMED AFTER ITS PLACE OF DISCOVERY, DARMSTADT

[281]

7	MELTING POINT	--- ℃
10	BOILING POINT	--- ℃
	DENSITY	--- g/cm³

112 コペルニシウム Copernicium

Cn 鎶

Radioactive
man-made

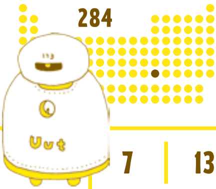
NAMED AFTER COPERNICUS, THE ASTRONOMER WHO PREACHED ABOUT THE HELIOCENTRIC THEORY

285

7	MELTING POINT	--- ℃
12	BOILING POINT	--- ℃
	DENSITY	--- g/cm³

113 ウンウントリウム **Ununtrium**

Uut

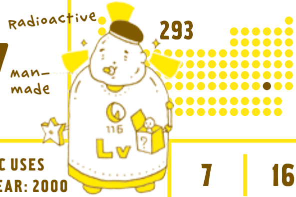


SCIENTIFIC USES
DISCOVERY YEAR: 2004

7 | 13

116 リバモリウム **Livermorium**

Lv

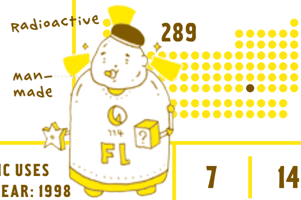


SCIENTIFIC USES
DISCOVERY YEAR: 2000

7 | 16

114 フレロビウム **Flerovium**

Fl

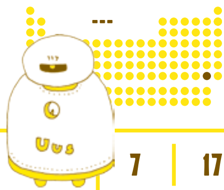


SCIENTIFIC USES
DISCOVERY YEAR: 1998

7 | 14

117 ウンウンセプチウム **Ununseptium**

Uus

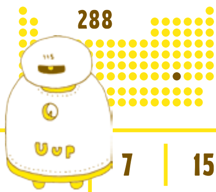


SCIENTIFIC USES
DISCOVERY YEAR: 2010

7 | 17

115 ウンウンペンチウム **Ununpentium**

Uup

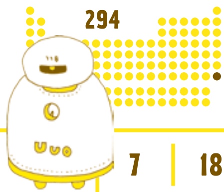


SCIENTIFIC USES
DISCOVERY YEAR: 2003

7 | 15

118 ウンウンオクチウム **Ununoctium**

Uuo



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!

1

Rh

RHODIUM
¥60,000
1G POWDER
(99.9% PURE)

2

Cs

CESIUM
¥52,400
1G ENCLOSED SAMPLE

3

Lu

LUTETIUM
¥50,500
1G FRAGMENT
(99.9% PURE)

4

Sc

SCANDIUM
¥45,900
1G INGOT
(99.9% PURE)

5

Tm

THULIUM
¥33,100
1G PELLET

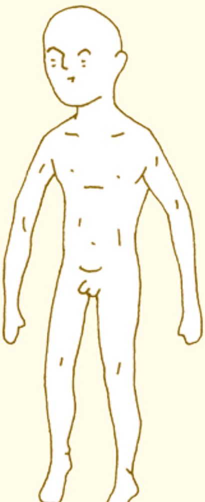
SOME PRECIOUS METALS FOR COMPARISON

PLATINUM	¥4,216
GOLD	¥3,139
SILVER	¥51.6

* 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

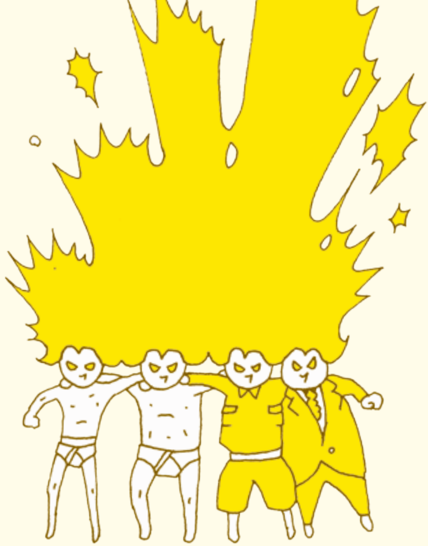
ELEMENT FRIENDS

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.

Nd Sm

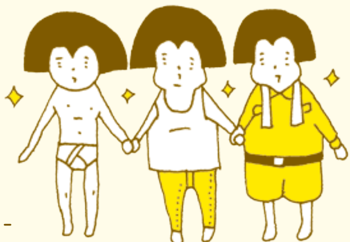
THE STRONGEST MAGNET COMBO IN THE WORLD

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.

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.



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)

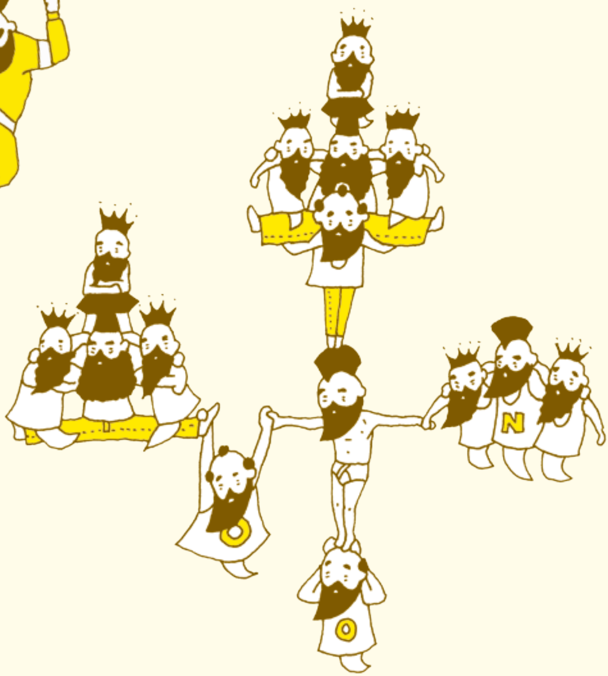
ARSENIC TRIOXIDE

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

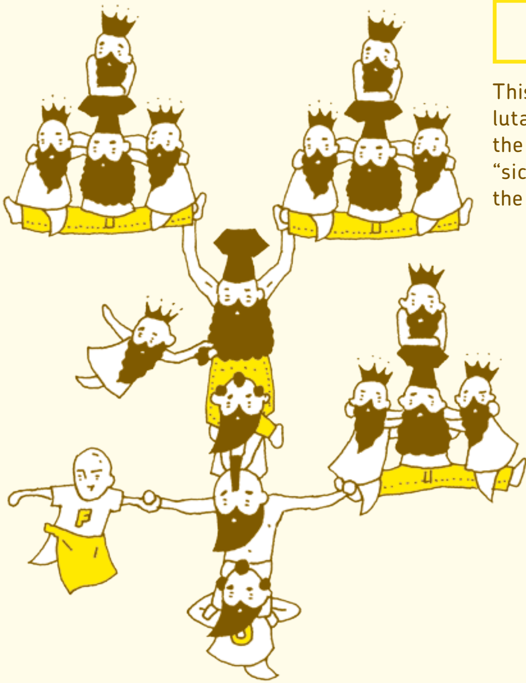
Methamidophos became famous in Japan when trace amounts of the poison were found in foodstuffs imported from China. It is made up of a multitude of elements.



$C_4H_{10}O_2FP$

SARIN

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



CH_2O

FORMALDEHYDE

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

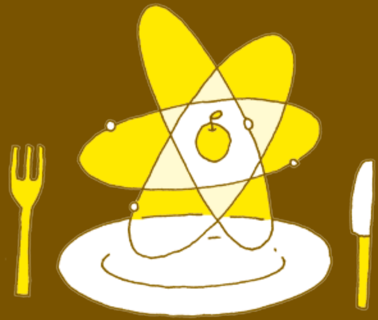
KCN

POTASSIUM CYANIDE

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


That's a wrap!
Is it... is it over?
Hehehe
Great work!!
Thud

4



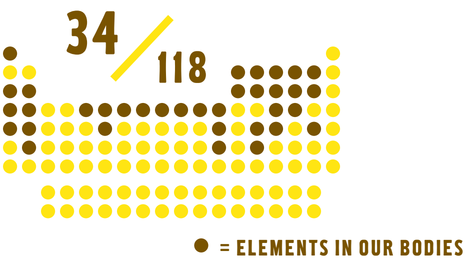
HOW TO EAT THE ELEMENTS
元素の食べ方

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.



THE ELEMENTS INSIDE OUR BODIES

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 %

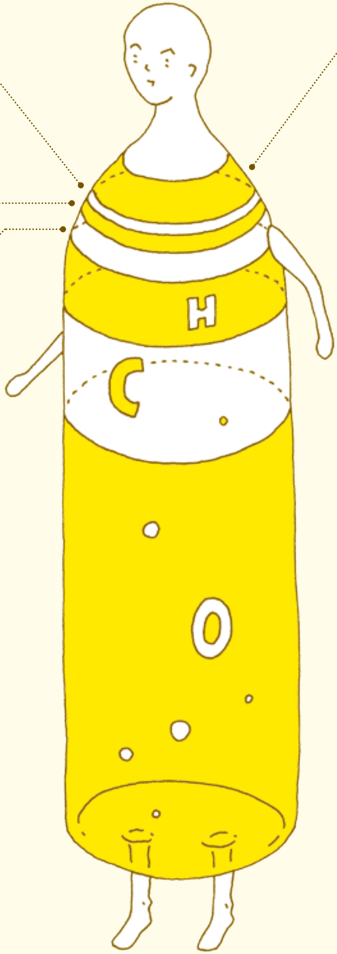
NITROGEN
3.0 %

HYDROGEN
10 %

CARBON
18 %

OXYGEN
65 %

★ = MINERALS



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

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

MAGNESIUM


Toasted nori


Spinach


Bananas


Kelp


Soybeans


Fish


Seaweed


Sesame

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)

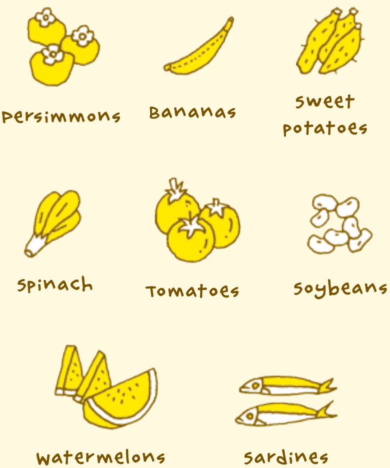
MEN
320 – 370 mg

WOMEN
260 – 290 mg

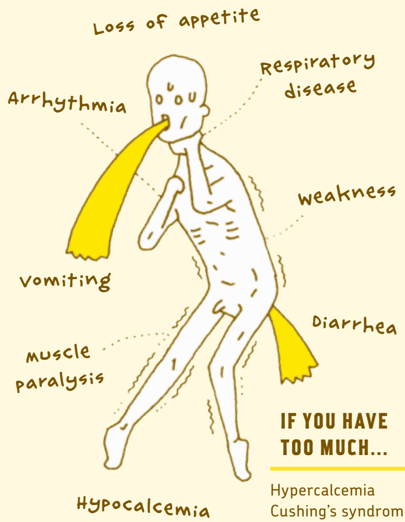
K

POTASSIUM

CAN BE FOUND IN



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

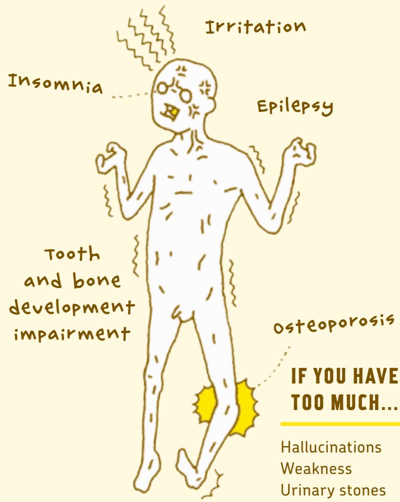
WOMEN
2000 mg

Ca

CALCIUM

CAN BE FOUND IN

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

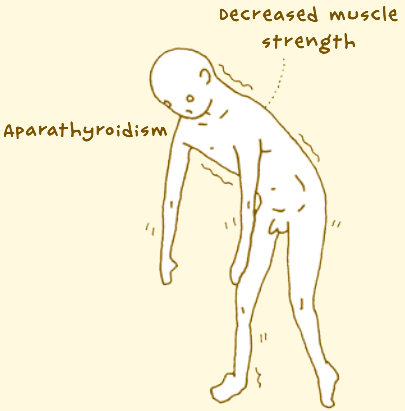
WOMEN
600 – 650 mg

P

CAN BE FOUND IN

PHOSPHORUS

IF YOU DON'T HAVE ENOUGH...



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

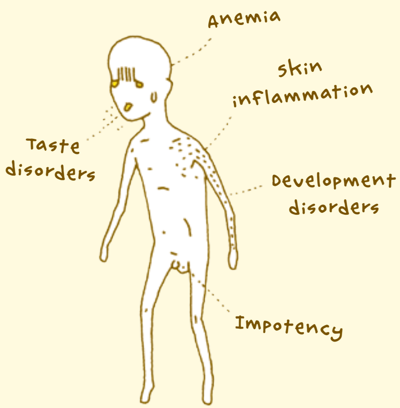
WOMEN
900 mg

Zn

ZINC

CAN BE FOUND IN

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

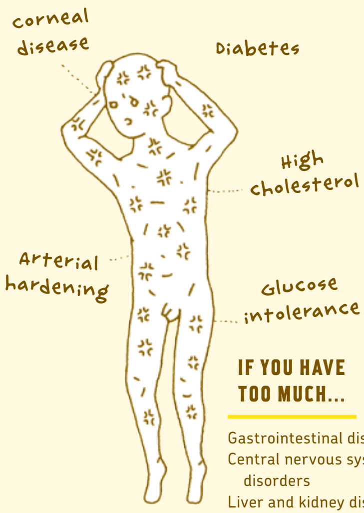
WOMEN
9 mg

Cr

CHROMIUM

CAN BE FOUND IN

IF YOU DON'T HAVE ENOUGH...



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

SELENIUM

IF YOU DON'T HAVE ENOUGH...

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

MOLYBDENUM

CAN BE FOUND IN

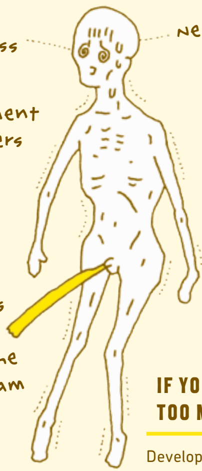
Liver

Grains

Beans

Dairy products

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

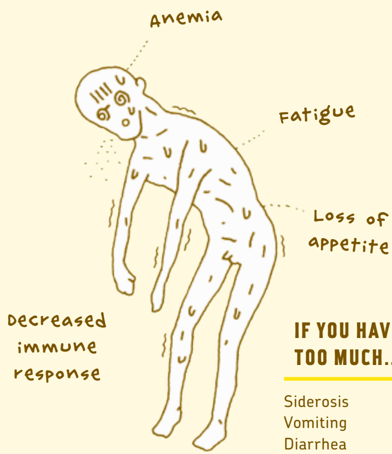
WOMEN
20 – 25 µg

Fe

IRON

CAN BE FOUND IN

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

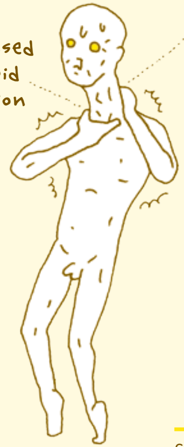
IODINE

CAN BE FOUND IN

Seaweeds

Fish and shellfish

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)

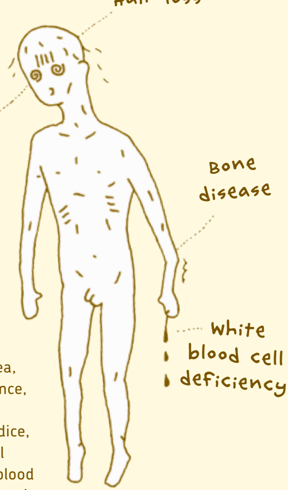
130 µg

Cu

COPPER

CAN BE FOUND IN

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

MANGANESE

CAN BE FOUND IN

Green tea

Seaweeds

Beef

Beans

Oysters

Powdered green tea

Clams

IF YOU DON'T HAVE ENOUGH...

Fat and sugar metabolism disorders

Development disorders

Pregnancy disorders (women)

Bone disease

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

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

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

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.

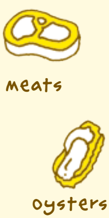
RECOMMENDED DAILY INTAKE (AVERAGE)

NOT NOTEWORTHY

Co

コバルト

Cobalt



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.

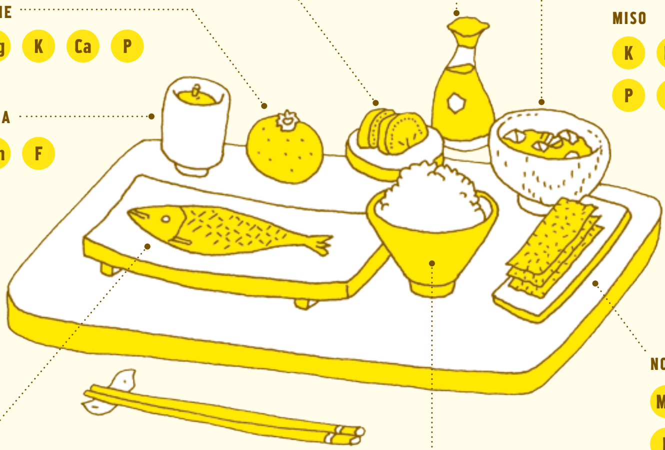
RECOMMENDED DAILY INTAKE (AVERAGE)

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

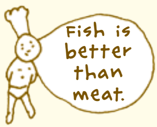
MISO SOUP WITH SEAWEED AND TOFU

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



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

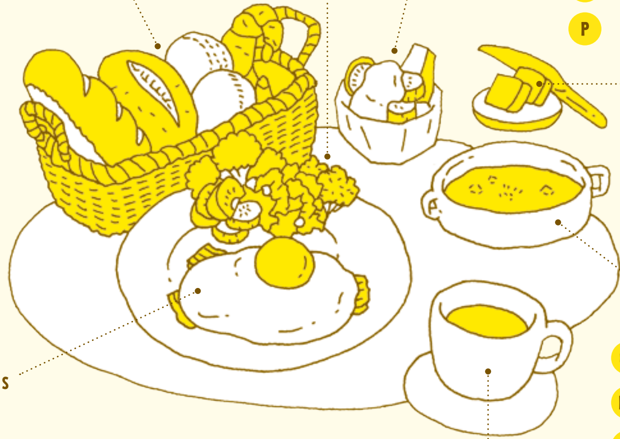
FRUIT YOGURT

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

BACON AND EGGS

BACON

P Cl Mg Na K S

BLACK PEPPER

Cr K

EGGS

Se Fe Ca P Cr S Zn Co K

COFFEE

K

Sprinkle a little salt on your eggs for more iodine.

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

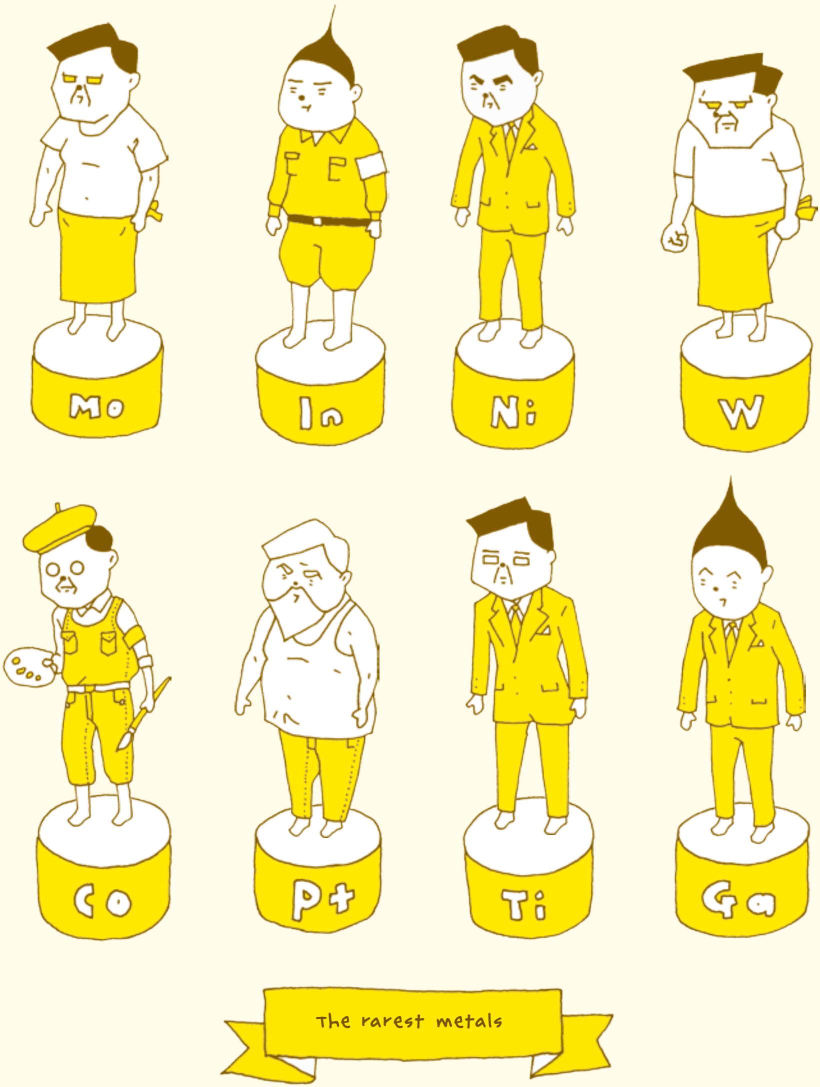
Some of the elements we've looked at so far, like germanium, were very popular a few years back but aren't really used any more. Other elements like indium only recently came into the spotlight.

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.

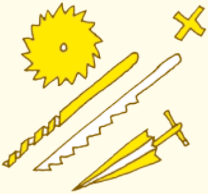

Mo
In
Ni
W
Co
Pt
Ti
Ga
The rarest metals

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.

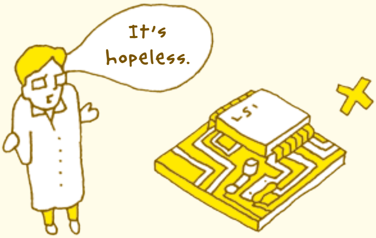
The popularity of some metals has driven their price up to the point that it's hard to acquire them at all. This is true not only for Japan but for the entire world. This makes the element crisis at least as serious as the impending oil crisis, and some countries have already begun stockpiling hard-to-find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



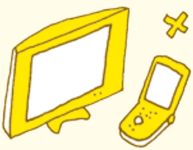
We won't be able to make strong tools without tungsten.

The manufacturing industry comes to a stop.



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.

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.

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

INDEX

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 Itsumonooto*), among others. Find out more about Bunpei and his works at *http://bunpei.com/*.

THE PRODUCTION TEAM FOR THE JAPANESE EDITION

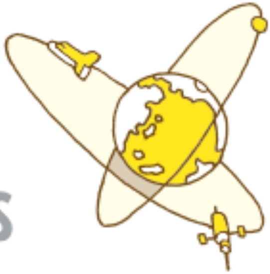
Book Design: Bunpei Yorifuji and Ayaka Kitatani
Publisher: Ryosuke Sone
Publishing House: Kagaku Dojin

THE PRODUCTION TEAM FOR THE ENGLISH EDITION

Publisher: William Pollock
Production Editor: Serena Yang
Developmental Editor: Keith Fancher
Translator: Fredrik Lindh
Technical Reviewer: Brandon Budde
Compositor: Riley Hoffman
Proofreader: Paula L. Fleming

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.

$17.95 ($18.95 CDN) SHELVE IN: Science

ISBN: 978-1-59327-423-8
51795
9 781593 274238
6 89145 74238 1