



CH-110 Advanced General Chemistry I

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French

- This part of the class will be taught **in English**.
- We will do our best to support you during this transition:
 - Recordings with French subtitles*
 - Lecture transcripts in French*
 - You can ask questions in French in class (I'll do my best!) and on the forum.*
 - Five of our six teaching assistants speak French (see separate slide).*
- For my part of the exam (atomic structure), the questions will be in English and in French. You can write your answers in English or French.

CH-110 Advanced General Chemistry (Fall 2025)

- Lectures:

Tuesday, 16:15-18:00, BCH 2201

*Friday, 11:15-12:00, ELA1 (**near construction!**)*

- Exercises:

Friday, 13:15-14:00, AAC231

Course organization and exam

- Part I: 9 weeks (A. Steinauer, atomic structure)
- Part II: 5 weeks (J. Waser, organic chemistry, in French)

- Two 3-hour written exams during the winter exam session 2025/26:
Steinauer/Waser (3 hours)
Fierz (3 hours)

- No material other than that provided is permitted during the examination.
- You will be provided with a periodic table and a list of formulas (see Moodle for last year's versions)

Changes compared to last year

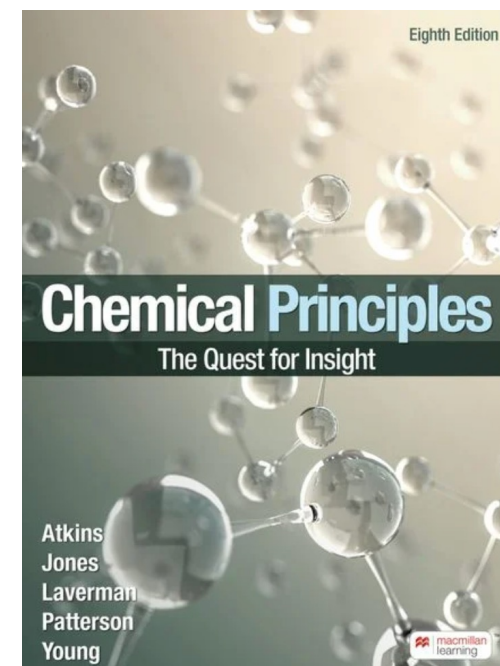
| Student feedback | Change this year |
|--|---|
| Too many slides | Will try to condense material, do the important parts on the blackboard |
| Not clear what students are expected to know at exam | Clearer communication: the exercises provided in class and in the book are the most important practice opportunity! |
| Exercises were not aligned with lecture material | I will double-check each week if there are exercises that you cannot solve because we didn't cover the material in class. |
| Not enough practice exams | There is one now. The best practice opportunity are the exercises in the book. |

Lecture content and exercises

- Syllabus online
- Textbook: Chemical Principles – The Quest for Insight by Atkins, Jones et al.
- Available at the EPFL bookstore
- Exercises:

Weekly. Not graded.

Form study groups!



Moodle

- <https://moodle.epfl.ch/course/view.php?id=15739>
- Slides, exercises, recordings will be uploaded weekly
- Forum to ask questions:
- <https://edstem.org/eu/courses/2603/discussion>
- Announcements

Teaching assistants

| Name | Languages | Email |
|------------------------|-------------------------|--|
| Georges Barnikol | Fr, En, German | georges.barnikol@epfl.ch |
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Georges



Paula



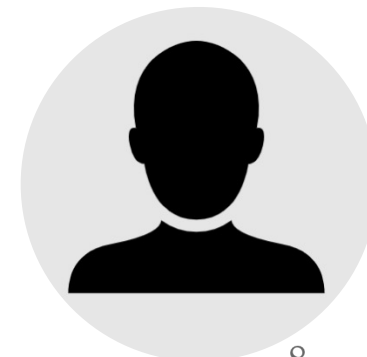
Ollie



Diogo



Yannick



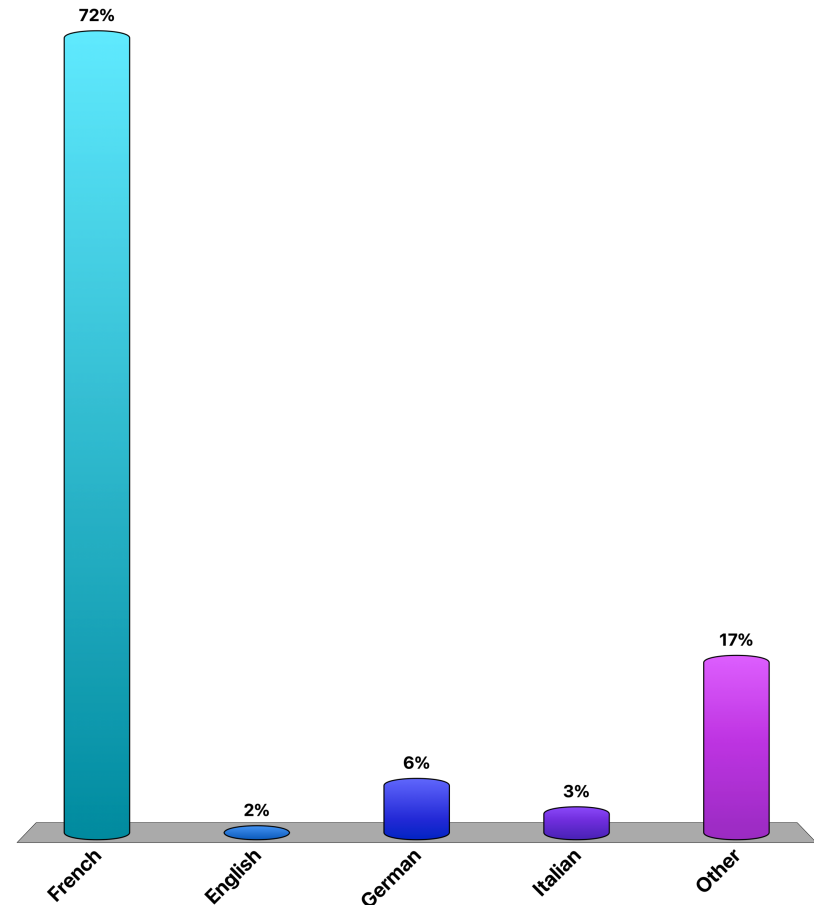
Tuna

Clicker questions

- <http://responseware.eu>
- Session ID: **858121**

What's your native language?

- A. French
- B. English
- C. German
- D. Italian
- E. Other



Session ID: 858121

What You Can Expect from Me

- **Dedication:** Preparing these lectures takes significant time, and I am committed to delivering quality content that helps you succeed.
- **Openness to feedback:** I am receptive to constructive feedback. You will have the opportunity to provide feedback through Moodle.
- **Answering questions:** I encourage you to attempt finding the answer yourself first. If needed, both the TAs and I are available to help guide you in the right direction.
- **Investment in your success:** I genuinely want you to do well and will support you in your academic journey!

What I Expect from You:

- **A respectful and productive classroom environment:** Please engage with the material and avoid distractions. If you need to discuss something with your peers during class, feel free to step outside and continue your discussion over coffee. I don't mind.
- **Curiosity and openness to learning:** Challenge yourself to ask, "Is this a question I could answer on my own with a bit of effort?"
- **Responsibility for learning:** You are responsible for your own learning. This means attending class and independently solving exercises, keeping up with the reading, and taking ownership of your progress.

A word about artificial intelligence

- AI chatbots can be useful tutors: you can ask follow-up questions when something is unclear.
- They work well for basic-level concepts but may give wrong or misleading information.
- AI does **not** replace solving the exercises yourself – that’s how you actually learn.
- Simulate exam conditions: **practice solving problems on your own.**
- Use our weekly exercises and additional ones in the book to practice. The solutions for the book’s exercises are on the Moodle.

How to study for this class

- Solve exercises! Weekly assigned problem sets and extra exercises in the book.
- Each sub-chapter has between 20-30 exercises you can use to practice.
- **I will use the exercises from class and from the book as a starting point to develop the exam questions.**
- You need the book for this class!
- You are not expected to be able to solve exercises that require calculus, they are labeled:

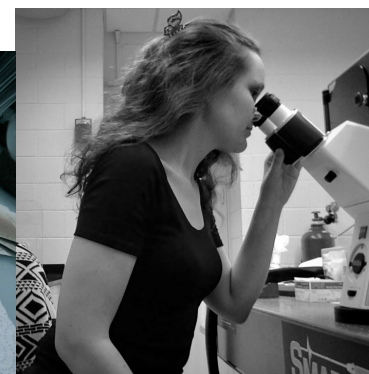
Les exercices marqués  demandent du calcul intégral.



Definition of Chemistry

- Chemistry is the science of matter and the changes it can undergo.

Why I studied chemistry

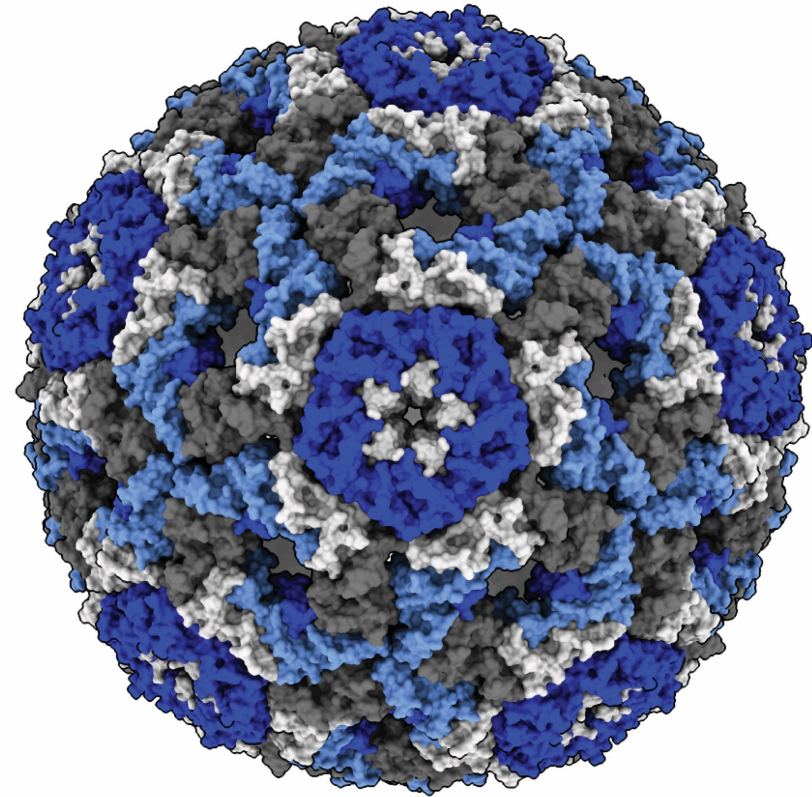
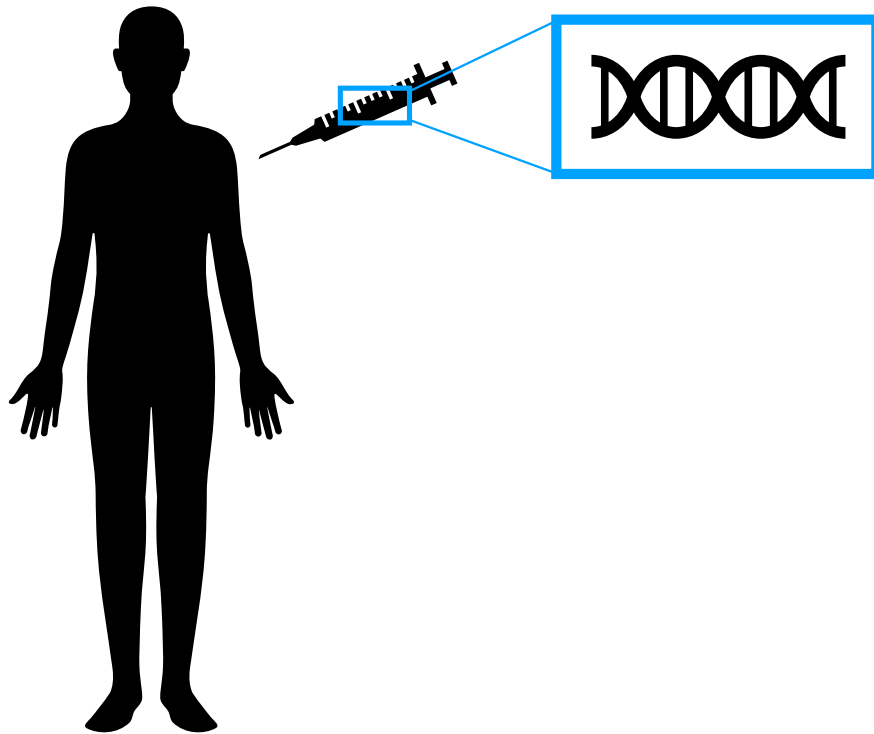


Why did you choose to study chemistry?

I LOVE COSMETIC STUFF BUT ALSO TO PROVE MY HS TEACHER WRONG
IT'S THE MOST INTERESTING PART OF SCIENCE !
CAUSE I LOVE COOKING AND BAKING ! I'M ALSO A HUGE FAN OF PERFUMES
I LIKE IT BY WATCHING SERIES ABOUT CHEMICAL ISSUES SUCH AS BREAKING BAD OR DEXTER. ALSO I LIKE TO WORK ON A LAB AND MY PROFESSOR SAID ME TO DO IT BECAUSE I WAS GOOD ON IT.
PHARMACEUTICALS AND COSMETICS INTERESTING AND FUN EXPERIMENTS
BECAUSE OF MY PASSION FOR THE BRANCH
TV SHOW DEXTER
I FOUND IT INTERESTING COMPLETE SCIENCE CRAZY RESULTS AFTER A REACTION
I WANT TO DO RESEARCH LAB INTERESTING
TO TEACH IT **BREAKING BAD** I LIKE THE LABS
TO WORK IN CBRN DEFENSE I LIKE EXPLOSIONS MONEY
BECAUSE I FIND IT FASCINATING THAT EVERYTHING THAT WE HAVE EVER SEEN IN OUR HISTORY AND THAT MIGHT COMPOSE THE ENTIRE UNIVERSE ONLY CONSISTS OF 118 OR SO ELEMENTS
A VERY PASSIONATE COLLEGE TEACHER
I CHOOSE CHEMISTRY BECAUSE I FIND IT VERY INTERESTING.
CAUSE I WOULD LIKE TO CREATE NEW SUBSTANCES
FIND AND INDUSTRIALIZE A SUSTAINABLE PETROL AND PLASTIC ALTERNATIVE TO COMBAT THE CLIMATE CRISIS
BECAUSE WHEN I WAS YOUNG I HAD SEEN MANY VIDEOS, AND I BECAME PASSIONATE BY THAT

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What can you do with this course?



Overview of this course

FOCUS 1: ATOMS

Topic 1A: Investigating Atoms

Topic 1B: Quantum Theory

Topic 1C: Wavefunctions and Energy Levels

Topic 1D: The Hydrogen Atom

Topic 1E: Many-Electron Atoms

Topic 1F: Periodicity

Chapters from “Chemical Principles – The Quest for Insight” Atkins, Jones, et al.

FOCUS 2: BONDS BETWEEN ATOMS

Topic 2A: Ionic Bonding

Topic 2B: Covalent Bonding

Topic 2C: Beyond the Octet Rule

Topic 2D: The Properties of Bonds

Topic 2E: The VSEPR Model

Topic 2F: Valence-Bond Theory

Topic 2G: Molecular Orbital Theory

FOCUS 3: STATES OF MATTER

Topic 3D: Intermolecular Forces

Topic 3F: Liquids

Topic 3G: Solids

Early chemists

- **al-kīmiyā (Arabic):** *The art of transformation/metallurgy*
- Translated to Latin/European languages: alchemy, "al-" (=the) was later dropped
- Alchemists prepared glass, jewels, coins, ceramics, and, inevitably, weapons
- Craftspeople and experimenters
- Developed techniques we still use, e.g. distillation
- Alchemy & mysticism:
The Philosopher's stone: a material that will turn cheap metals into gold and silver

The Alchemist

Ink on paper attributed to Philip Galle after Pieter Bruegel the Elder (c. 1558)



Shift towards science

- **Paracelsus** (1493-1541): pushed chemistry for medicine
- **Robert Boyle** (*The Skeptical Chymist*, 1661): emphasized experiment and reproducibility
- **Separation**: mystical alchemy vs. empirical chemistry

Paracelsus:

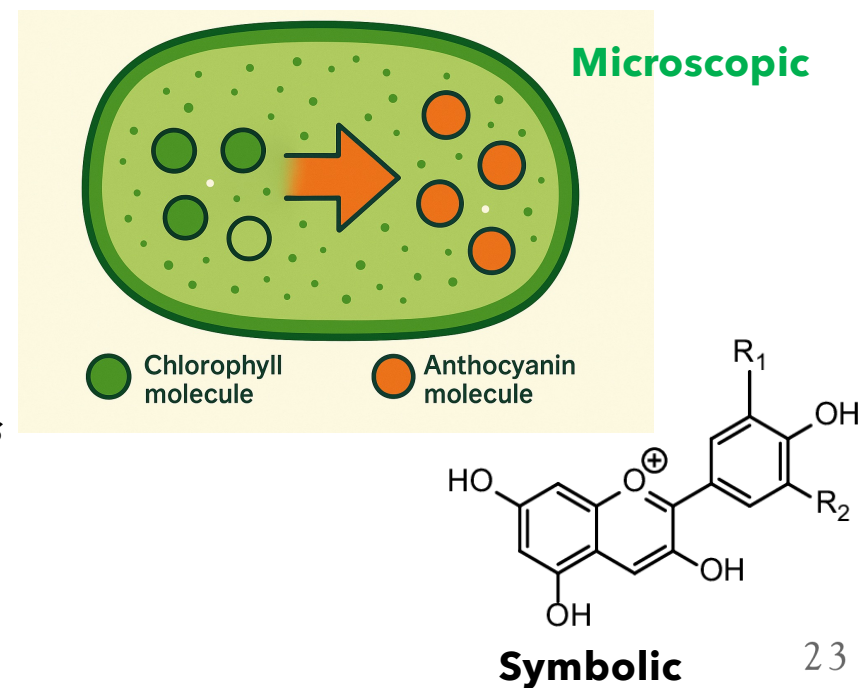
"All things are poison, and nothing is without poison; only the dose makes a thing not a poison."

"Omnia sunt venena, nihil est sine veneno. Sola dosis facit, ut venenum non sit."

Chemistry is a science at three levels

- **Macroscopic:** Matter and transformations (a leaf turns orange).
- **Microscopic:** (Re)arrangement of atoms (molecular changes that make the leave turn orange).
- **Symbolic:** Chemical symbols and mathematical equations.

A chemist thinks at the microscopic level, conducts experiments at the macroscopic level, and represents both symbolically.



How science is done: The scientific method

- **Meticulously careful** and **highly creative**

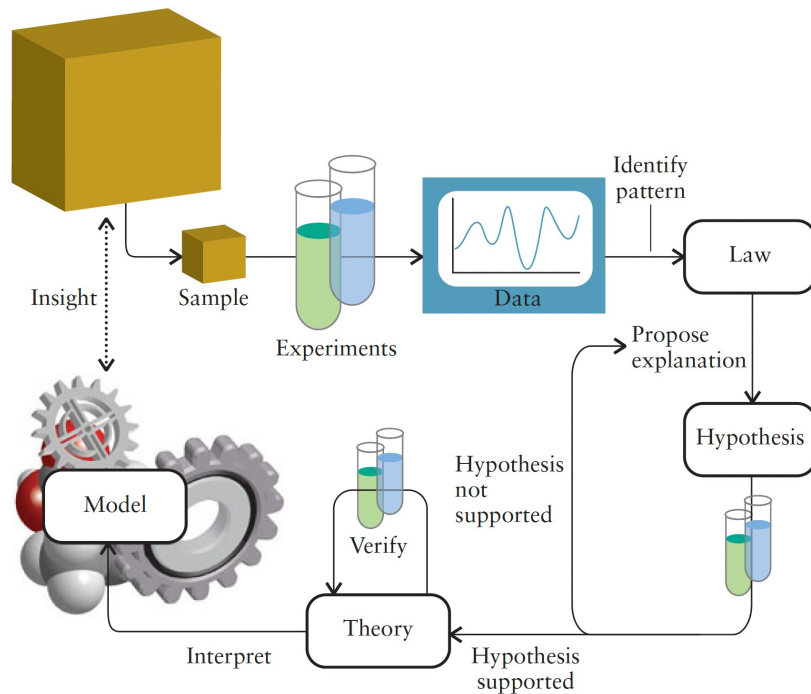


Figure 4

- **Law:** succinct summary of a wide range of observations
- **Hypothesis:** possible explanation of the law
- **Theory:** formal explanation of the law
- **Model:** a simplified version of the object of study that scientists can use to make predictions

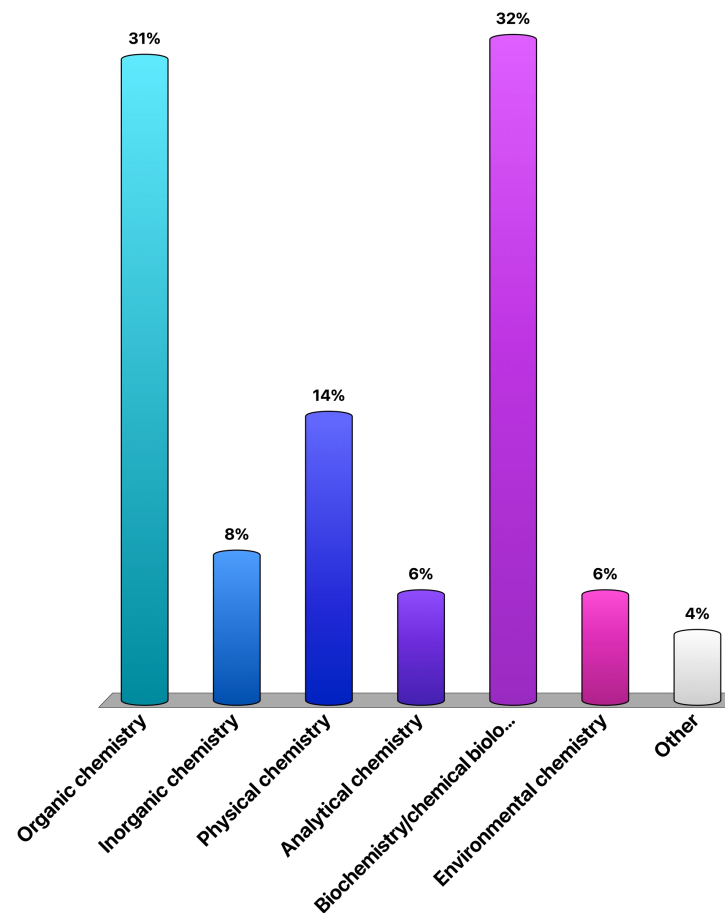
Not always linear!

Branches of chemistry

- **Organic Chemistry:** Carbon compounds, hydrocarbons, biomolecules
- **Inorganic Chemistry:** Metals, minerals, non-organic compounds
- **Physical Chemistry:** Thermodynamics, kinetics, quantum & computational chemistry
- **Analytical Chemistry:** Composition, techniques, instrumentation
- **Biochemistry/Chemical Biology/Biological Chemistry:** Enzymes, proteins, nucleic acids, metabolism, biomedical applications
- **Environmental Chemistry:** Pollution, green chemistry, ecosystems

Which subfield of chemistry are you (currently) most interested in?

- A. Organic chemistry
- B. Inorganic chemistry
- C. Physical chemistry
- D. Analytical chemistry
- E. Biochemistry/chemical biology
- F. Environmental chemistry
- G. Other



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Fundamentals

Please review Fundamentals A yourself (slides on Moodle: CH-110_EXTRA_FundamentalsA):

A: Matter and Energy

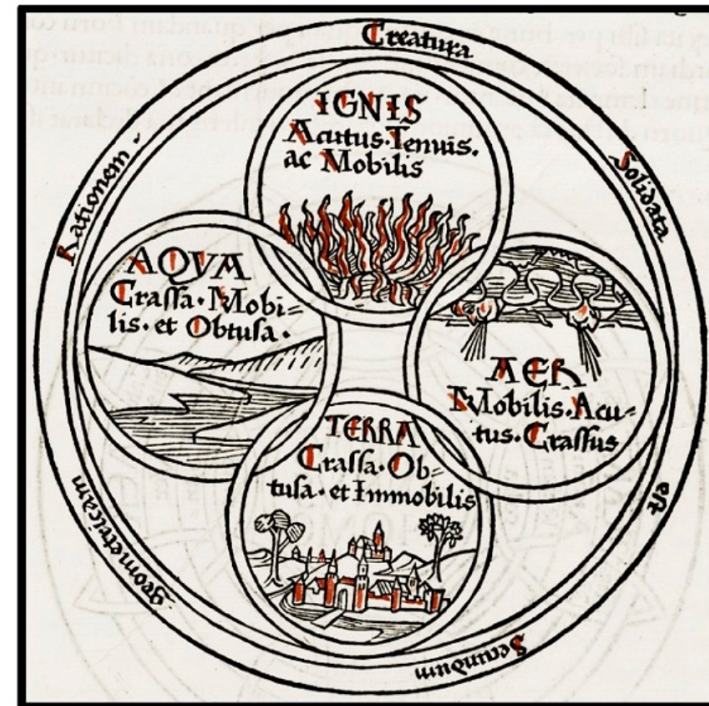
B: Elements and Atoms

Science: how are things organized? A quest for simplicity

Ancient Greek:

four elements: water, earth, fire, air

Today: +100 elements



De responsione et de astrorum ordinatione

Yale Beinecke Rare Book and Manuscript Library (1472)

Atoms

- What is the smallest unit of matter? Can you cut matter into ever smaller pieces?

The atom (greek: not cuttable)

- First convincing argument for atom:

1807 English schoolteacher and chemist John Dalton

- He measured ratios of masses of elements that combine together to form substances now called "compounds" (ratios form patterns).
- For example: in every sample of water, there is 8 g of oxygen for every 1 g of hydrogen.

Individual atoms by scanning tunneling microscopy

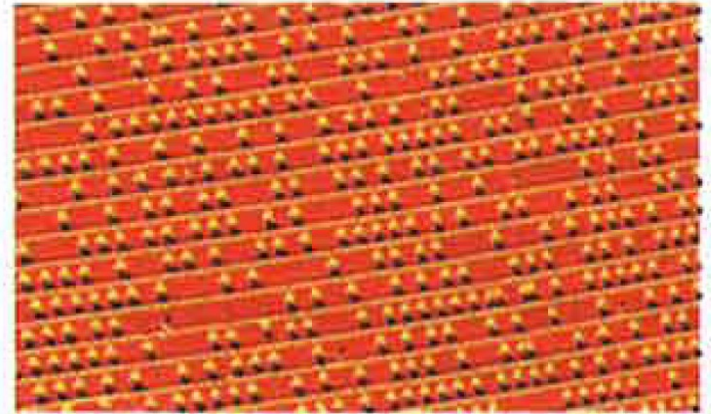


Figure B.3

Atomic hypothesis (Dalton)

1. All atoms of a given element are identical.
2. The atoms of different elements have different masses.
3. A compound is a specific combination of atoms of more than one element.
4. In a chemical reaction, atoms are neither created nor destroyed, they exchange partners to produce new substances.

All matter is made up of various combinations of the simple forms of matter called the chemical elements. An element is a substance composed of only one kind of atom.

The nuclear model

1. A small, positively charged nucleus (most of mass) made of protons (denoted p) and electrically neutral neutrons (denoted n)
2. Surrounded by a negatively charged electron (denoted e⁻)

TABLE B.1 The Properties of Subatomic Particles Relevant to Chemistry

| Particle | Symbol | Charge/e* | Mass/kg |
|----------|----------------|-----------|-------------------------|
| electron | e ⁻ | -1 | 9.109×10^{-31} |
| proton | p | +1 | 1.673×10^{-27} |
| neutron | n | 0 | 1.675×10^{-27} |

* Charges are given as multiples of the fundamental charge, which in SI units is $e = 1.602 \times 10^{-19}$ C (see Appendix 1B).

The nuclear model

Analogy: fly at the center of baseball field = nucleus
Electron space: entire stadium

Atoms are neutrally charged.

It follows: number of e^- = number of p

Atomic number, Z , of an element is the number of protons in the nucleus of one of its atoms.

Hydrogen: $Z = 1$

Helium: $Z = 2$, etc.



Figure B.4

Mass spectrometry

A mass spectrometer is a device that measures the mass of an atom.

$$m_H = 1.67 \times 10^{-27} \text{ kg}$$

$$m_C = 1.99 \times 10^{-26} \text{ kg}$$

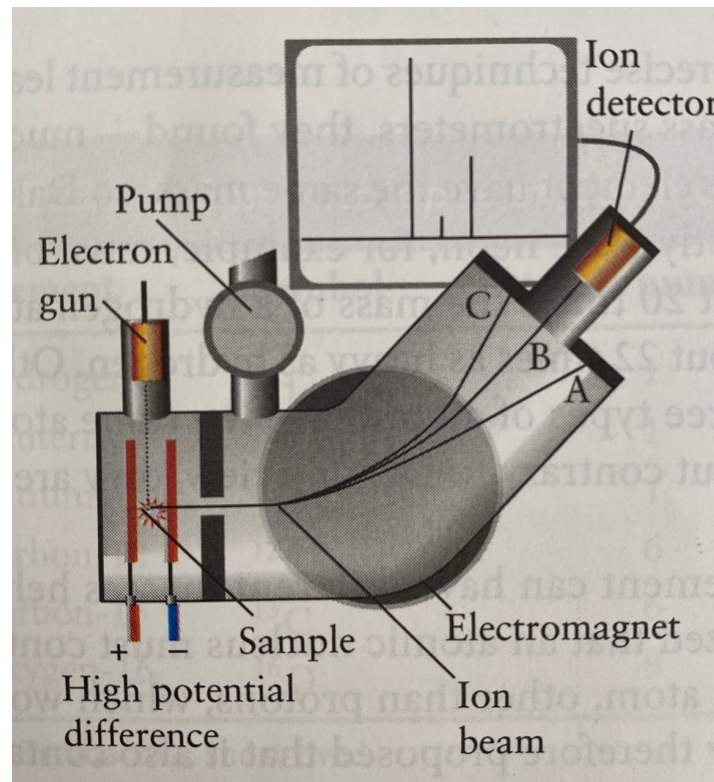


Figure B.5

1. Electrons from electron gun ionize sample
2. Created ions are accelerated through potential difference
3. Pass through electromagnetic field (tunable)
4. Pump removes air
5. **Mass/charge of ion proportional to the strength of magnetic field needed to move the beam into position to hit the detector**

Isotopes

MS: not all atoms of one element have the same mass! Dalton wasn't 100% right.

Neutrons!

- No Charge
- Roughly same mass as protons
- Neutrons + protons = nucleons

Isotope from Greek "same place"

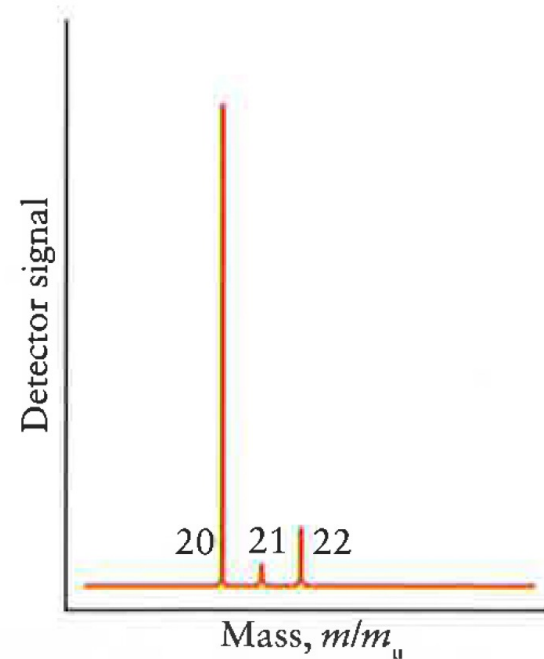


Figure B.6

Isotopes and mass number

The mass number is the total number of protons and neutrons in a nucleus.

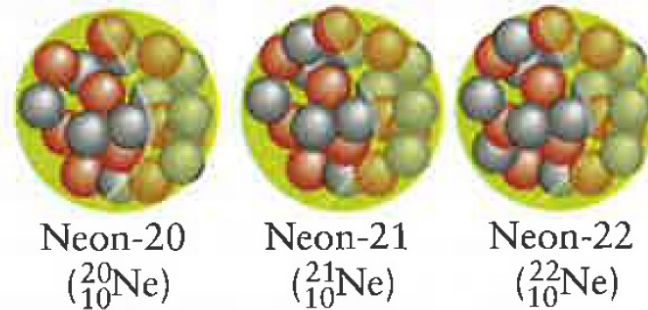


Figure B.7

An isotope has **the same atomic number**, but a **different mass number**.

Isotopes have the same physical and chemical properties with some important exceptions.

Isobars atoms of different atomic numbers that nevertheless have the same mass number.

Isotopes and mass number

TABLE B.2 Some Isotopes of Common Elements

| Element | Symbol | Atomic number, Z | Mass number, A | Abundance/% |
|-----------|---------------------|--------------------|------------------|-------------|
| hydrogen | ${}^1\text{H}$ | 1 | 1 | 99.985 |
| deuterium | ${}^2\text{H}$ or D | 1 | 2 | 0.015 |
| tritium | ${}^3\text{H}$ or T | 1 | 3 | —* |
| carbon-12 | ${}^{12}\text{C}$ | 6 | 12 | 98.90 |
| carbon-13 | ${}^{13}\text{C}$ | 6 | 13 | 1.10 |
| oxygen-16 | ${}^{16}\text{O}$ | 8 | 16 | 99.76 |

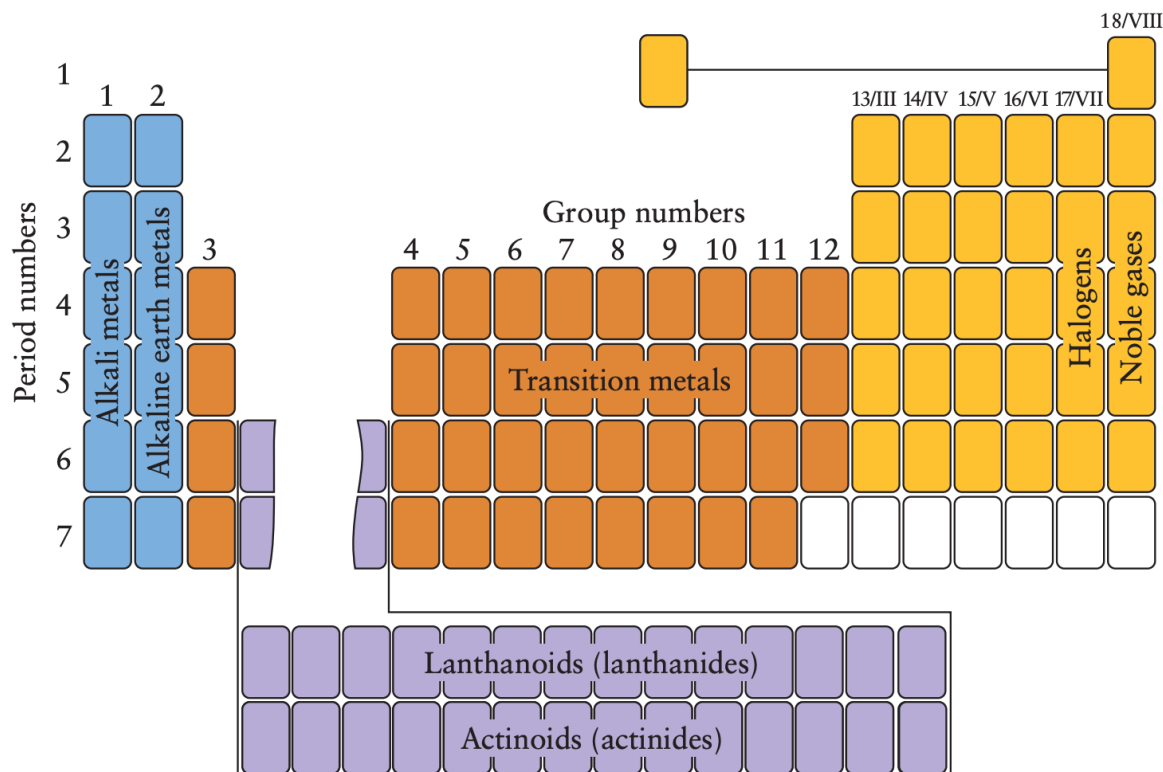
* Radioactive, short-lived.

When the term **nuclide** was first introduced, it referred to the bare nucleus; in its modern usage, it refers to the **entire atom**.

The organization of the elements

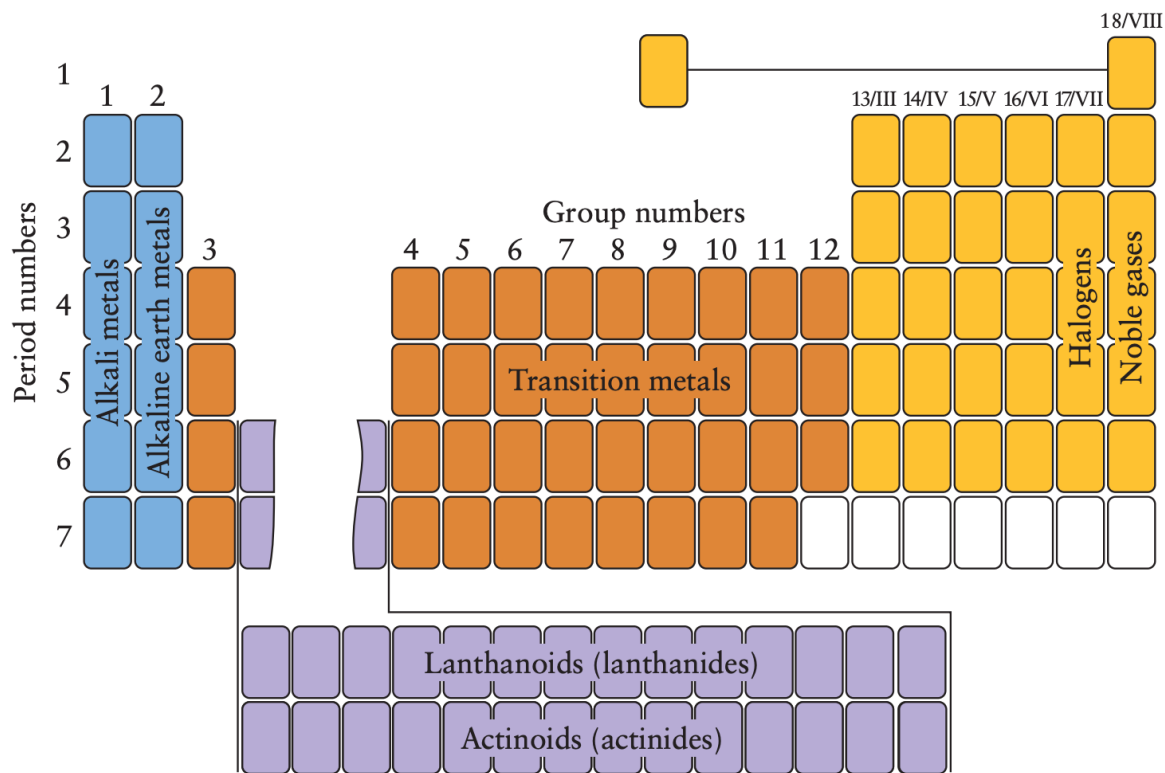
- Each element has a name and a unique chemical symbol made of one or two letters
- Chemical symbol: e.g. for helium, He
- The first letter uppercase, the second letter lowercase (He *not* HE)
- Currently 118 known elements (2024)
- 88 occur in significant quantities on earth

The periodic table



- Elements listed in order of their atomic number
- Arranged in rows of certain lengths
- Form families that show regular trends in properties
- **Groups:** vertical columns (18 groups), principal families of elements, numbered from left to right
- **Main group elements:** 1,2 and 13-18
- **Periods:** horizontal rows, numbered from the top down
- **Blocks** (in colors): s, p, d, f block elements (see Topic 1D)
- **Transition metals** (d-block without group 12)
- **Inner transition metals:** lanthanides (after lanthanum, element 57) and actinides (after actinium, element 89)

The periodic table



- Group 1: alkali metals
- Group 2: the alkaline earth metals
- Group 17: halogens
- Group 18: noble gases
- Hydrogen: sometimes in group 1, sometimes in group 17, here: special place in between
- **Most elements are solid metals.**
- Only two elements are liquid at room temperature: bromine and mercury.
- Only 11 are gases.

The periodic table

Elements are classified as:

- A **metal** conducts electricity, has a luster, malleable, ductile
- A **nonmetal** does not conduct electricity and is neither malleable nor ductile.
- A **metalloid** is an element of intermediate character. Typically, a metalloid has the physical properties of a metal but the chemical properties of a nonmetal.

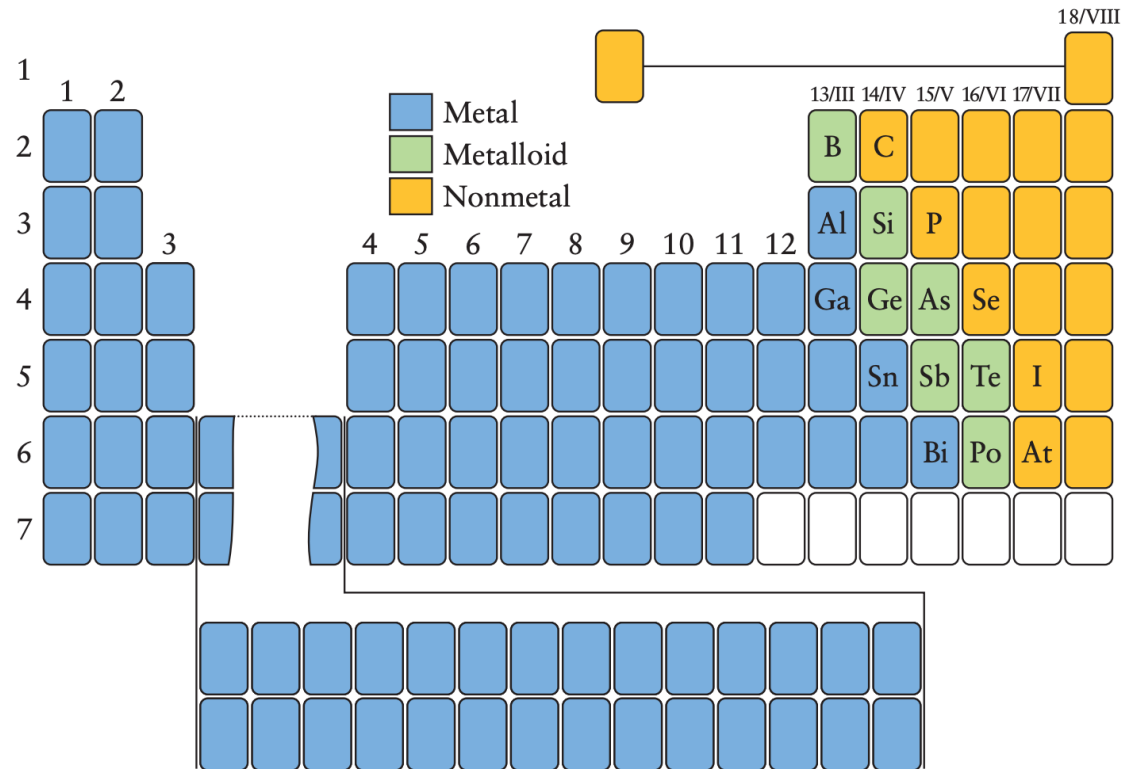


Figure B.10

PERIODIC TABLE OF THE ELEMENTS

| Group | 1 | 2 | Period 1 | | | | | | | | | | 13 | 14 | 15 | 16 | 17 | 18 |
|-------|---|--|---|---|--|--|--|--|--|--|--|--|---|---|--|--|--|--|
| | I | II | | | | | | | | | | | III | IV | V | VI | VII | VIII |
| | IA | IIA | | | | | | | | | | | IIIA | IVA | VA | VIA | VIIA | VIIIA |
| | 3 Li lithium 6.94 2s ¹ | 4 Be beryllium 9.01 2s ² | 1 H hydrogen 1.0079 1s ¹ | | | | | | | | | | 5 B boron 10.81 2s ² 2p ¹ | 6 C carbon 12.01 2s ² 2p ² | 7 N nitrogen 14.01 2s ² 2p ³ | 8 O oxygen 16.00 2s ² 2p ⁴ | 9 F fluorine 19.00 2s ² 2p ⁵ | 10 Ne neon 20.18 2s ² 2p ⁶ |
| 2 | | | | | | | | | | | | | | | | | | |
| 3 | 11 Na sodium 22.99 3s ¹ | 12 Mg magnesium 24.31 3s ² | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 Al aluminum 26.98 3s ² 3p ¹ | 14 Si silicon 28.09 3s ² 3p ² | 15 P phosphorus 30.97 3s ² 3p ³ | 16 S sulfur 32.06 3s ² 3p ⁴ | 17 Cl chlorine 35.45 3s ² 3p ⁵ | 18 Ar argon 39.95 3s ² 3p ⁶ |
| 4 | 19 K potassium 39.10 4s ¹ | 20 Ca calcium 40.08 4s ² | 21 Sc scandium 44.96 3d ¹ 4s ² | 22 Ti titanium 47.87 3d ² 4s ² | 23 V vanadium 50.94 3d ³ 4s ² | 24 Cr chromium 52.00 3d ⁴ 4s ¹ | 25 Mn manganese 54.94 3d ⁵ 4s ² | 26 Fe iron 55.84 3d ⁶ 4s ² | 27 Co cobalt 58.93 3d ⁷ 4s ² | 28 Ni nickel 58.69 3d ⁸ 4s ² | 29 Cu copper 63.55 3d ¹⁰ 4s ¹ | 30 Zn zinc 65.41 3d ¹⁰ 4s ² | 31 Ga gallium 69.72 4s ² 4p ¹ | 32 Ge germanium 72.64 4s ² 4p ² | 33 As arsenic 74.92 4s ² 4p ³ | 34 Se selenium 78.96 4s ² 4p ⁴ | 35 Br bromine 79.90 4s ² 4p ⁵ | 36 Kr krypton 83.80 4s ² 4p ⁶ |
| 5 | 37 Rb rubidium 85.47 5s ¹ | 38 Sr strontium 87.62 5s ² | 39 Y yttrium 88.91 4d ¹ 5s ² | 40 Zr zirconium 91.22 4d ² 5s ² | 41 Nb niobium 92.91 4d ⁴ 5s ¹ | 42 Mo molybdenum 95.94 4d ⁵ 5s ¹ | 43 Tc technetium (98) 4d ⁵ 5s ² | 44 Ru ruthenium 101.07 4d ⁷ 5s ¹ | 45 Rh rhodium 102.90 4d ⁸ 5s ¹ | 46 Pd palladium 106.42 4d ¹⁰ | 47 Ag silver 107.87 4d ¹⁰ 5s ¹ | 48 Cd cadmium 112.41 4d ¹⁰ 5s ² | 49 In indium 114.82 5s ² 5p ¹ | 50 Sn tin 118.71 5s ² 5p ² | 51 Sb antimony 121.76 5s ² 5p ³ | 52 Te tellurium 127.60 5s ² 5p ⁴ | 53 I iodine 126.90 5s ² 5p ⁵ | 54 Xe xenon 131.29 5s ² 5p ⁶ |
| 6 | 55 Cs cesium 132.91 6s ¹ | 56 Ba barium 137.33 6s ² | 57 La lanthanum 138.91 5d ¹ 6s ² | 72 Hf hafnium 178.49 5d ² 6s ² | 73 Ta tantalum 180.95 5d ³ 6s ² | 74 W tungsten 183.84 5d ⁴ 6s ² | 75 Re rhenium 186.21 5d ⁵ 6s ² | 76 Os osmium 190.23 5d ⁶ 6s ² | 77 Ir iridium 192.22 5d ⁷ 6s ² | 78 Pt platinum 195.08 5d ⁹ 6s ¹ | 79 Au gold 196.97 5d ¹⁰ 6s ¹ | 80 Hg mercury 200.59 5d ¹⁰ 6s ² | 81 Tl thallium 204.38 6s ² 6p ¹ | 82 Pb lead 207.2 6s ² 6p ² | 83 Bi bismuth 208.98 6s ² 6p ³ | 84 Po polonium (209) 6s ² 6p ⁴ | 85 At astatine (210) 6s ² 6p ⁵ | 86 Rn radon (222) 6s ² 6p ⁶ |
| 7 | 87 Fr francium (223) 7s ¹ | 88 Ra radium (226) 7s ² | 89 Ac actinium (227) 6d ¹ 7s ² | 104 Rf rutherfordium (261) 6d ² 7s ² | 105 Db dubnium (262) 6d ³ 7s ² | 106 Sg seaborgium (266) 6d ⁴ 7s ² | 107 Bh bohrium (264) 6d ⁵ 7s ² | 108 Hs hassium (267) 6d ⁶ 7s ² | 109 Mt meitnerium (268) 6d ⁷ 7s ² | 110 Ds darmstadtium (271) 6d ⁸ 7s ² | 111 Rg roentgenium (272) 6d ⁹ 7s ¹ | 112* | 113 | 114 | 115 | 116 | 117 | 118 |
| | | | Lanthanoids (lanthanides) 6 | | 58 Ce cerium 140.12 4f ¹ 5d ¹ 6s ² | 59 Pr praseodymium 140.91 4f ³ 6s ² | 60 Nd neodymium 144.24 4f ⁴ 6s ² | 61 Pm promethium (145) 4f ⁵ 6s ² | 62 Sm samarium 150.36 4f ⁶ 6s ² | 63 Eu europium 151.96 4f ⁷ 6s ² | 64 Gd gadolinium 157.25 4f ⁷ 5d ¹ 6s ² | 65 Tb terbium 158.93 4f ⁹ 6s ² | 66 Dy dysprosium 162.50 4f ¹⁰ 6s ² | 67 Ho holmium 164.93 4f ¹¹ 6s ² | 68 Er erbium 167.26 4f ¹² 6s ² | 69 Tm thulium 168.93 4f ¹³ 6s ² | 70 Yb ytterbium 173.04 4f ¹⁴ 6s ² | 71 Lu lutetium 174.97 5d ¹ 6s ² |
| | | | Actinoids (actinides) 7 | | 90 Th thorium 232.04 6d ² 7s ² | 91 Pa protactinium 231.04 5f ² 6d ¹ 7s ² | 92 U uranium 238.03 5f ³ 6d ¹ 7s ² | 93 Np neptunium (237) 5f ⁴ 6d ¹ 7s ² | 94 Pu plutonium (244) 5f ⁶ 7s ² | 95 Am americium (243) 5f ⁷ 7s ² | 96 Cm curium (247) 5f ⁸ 6d ¹ 7s ² | 97 Bk berkelium (247) 5f ⁹ 7s ² | 98 Cf californium (251) 5f ¹⁰ 7s ² | 99 Es einsteinium (252) 5f ¹¹ 7s ² | 100 Fm fermium (257) 5f ¹² 7s ² | 101 Md mendelevium (258) 5f ¹³ 7s ² | 102 No nobelium (259) 5f ¹⁴ 7s ² | 103 Lr lawrencium (262) 6d ¹ 7s ² |

Molar masses (atomic weights) quoted to the number of significant figures given here can be regarded as typical of most naturally occurring samples.

*The names of the elements 112 and higher have not yet been determined; both 112 and 114 have been confirmed.

The skills you have mastered are the ability to

- ❑ Describe the structure of an atom.
- ❑ Find the number of atoms in a sample of an element of given mass.
- ❑ State the number of neutrons, protons, and electrons in a nuclide.
- ❑ Write the symbols of the elements.
- ❑ Describe the organization of the periodic table and the characteristics of elements in different regions of the table.

Summary: The periodic table is an arrangement of the elements by atomic number that reflects their family relationships; members of the same group typically show a smooth trend in properties.

Preview Chapter 1 (Focus 1: Atoms)

