CH-110 Advanced General Chemistry I

Prof. A. Steinauer

angela.steinauer@epfl.ch

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.

  Three of our six teaching assistants speak French (see separate slide).
- For the Steinauer part of the exam (atomic structure), the questions will be in English and in French. We will ask you to write your answers **in English.**

CH-110 Advanced General Chemistry (Fall 2024)

- Lectures:

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

  Friday, 11:15-12:00, PO01

- 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 2024/25:

  Steinauer/Waser (3 hours)

  Fierz (3 hours)

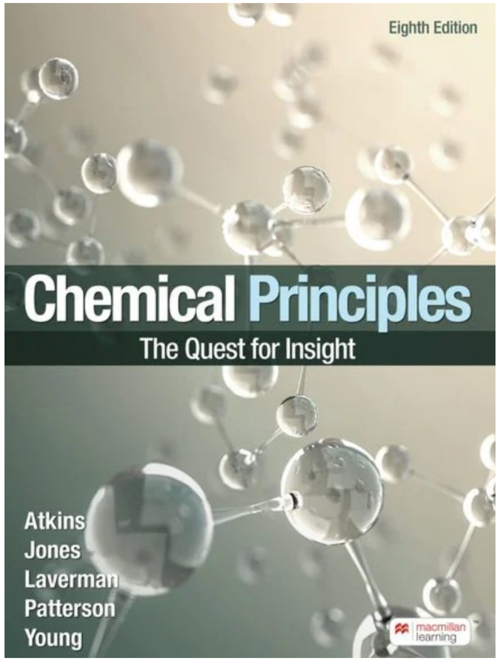
- No material other than that provided is permitted during the examination.
- You will be provided with a periodic table and a list of formulas.

Lecture content and exercises

- Syllabus online
- Textbook: Chemical Principles – The Quest for Insight by Atkins, Jones et al.
- Find the book on Orell Füssli or Amazon:
- https://www.orellfuessli.ch/shop/home/artikeldetails/A1067522642
- https://www.amazon.com/Chemical-Principles-Insight-Peter-Atkins/dp/1464183953/ref=sr_1_1?crid=U88HS9HOU4YV&dib=eyJ2IjoiMSJ9.3KYTAOvBNOi1ipn5XaTpt1ZRG7VDXDvw_PZEsdbuU8c.A357JJtEiOPJyeutWCYxcoy8oWIE1CJWSqJ0Zt1ZMy4&dib_tag=se&keywords=Chemical+Principles%3A+The+Quest+for+Insight+eight&qid=1726046616&s=books&sprefix=chemical+principles+the+quest+for+insight+eigh%2Cstripbooks-intl-ship%2C210&sr=1-1
- 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/1538/discussion/
- Announcements

Teaching assistants

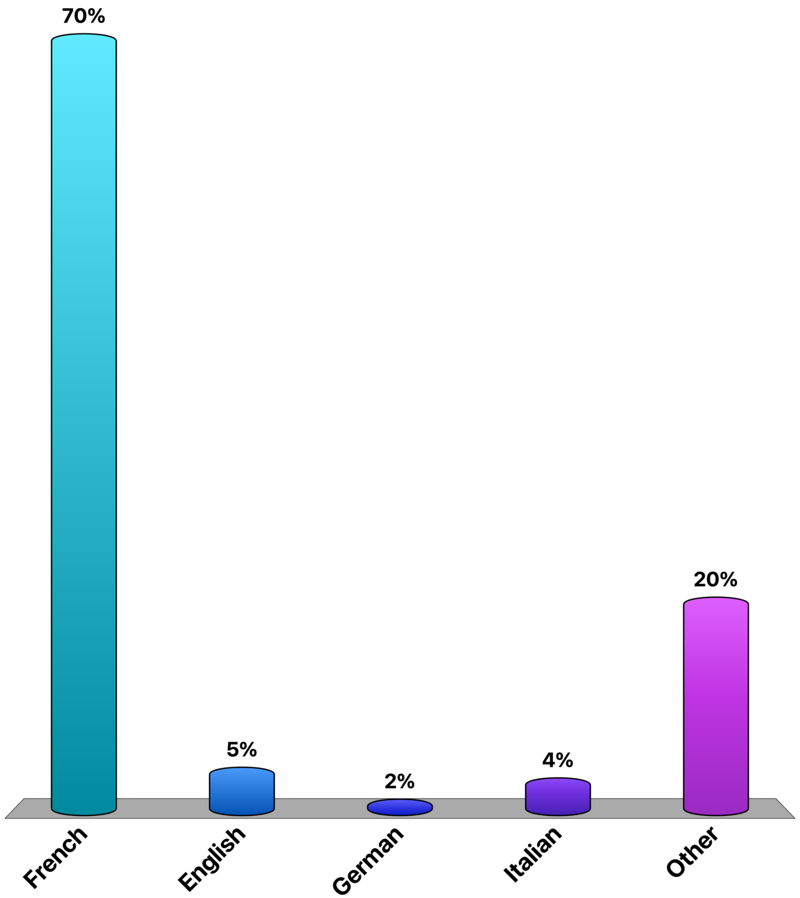
- Andrea Melgar, andrea.melgaraguilar@epfl.ch
- Georges Barnikol (speaks French), georges.barnikol@epfl.ch
- Paula Oeser (speaks French), paula.oeser@epfl.ch
- Ümmügülsüm Günes, ummugulsum.gunes@epfl.ch
- Yannick Calvino Alonso (speaks French), yannick.calvinoalonso@epfl.ch
- Yuri Cho, yuri.cho@epfl.ch

Clicker questions

- http://responseware.eu
- Session ID: 334378

What's your native language?

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



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 at least once a week after class.
- **Answering Questions:** I may not always know the answer immediately. If that's the case, 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:

- **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 their own learning. This means attending class and independently solving exercises, keeping up with the reading, and taking ownership of your progress.
- **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, keep your conversation quiet so as not to disturb others. If the matter is urgent and can't wait, feel free to step outside and continue your discussion over coffee. I don’t mind.

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?

CHEMISTRY CAN EXPLAIN THE WORLD IN WHICH WE LIVE. AND THERE IS LOT OF DIFFERENT THINGS WE CAN STUDY IN CHEMISTRY.

I CHOOSE CHEMISTRY BECAUSE OF THE FUN THAT I HAD DOING EXPERIENCE AT THE SCHOOL SO I FOUND THIS SUBJECT SO FUN

IF ONLY I KNEW HAHAHA, THAT SUBJECT DREW MY ATTENTION FROM A YOUNG AGE, AND I HAVE BEEN HOOKED SINCE 😊

I DID AN INTERNSHIP WITH SEARCHERS OF CNRS. I LOVE THE DIVERSITY OF THE SUBJECT.

I BELIEVE CHEMISTRY IS THE MOST PROMISING FIELD NOWADAYS, BECAUSE IT CAN BE INTEGRATED WITH PHYSICS, BIOLOGY, INFORMATICS ABD SO MUCH MORE WITHOUT LIMITS

IT'S FUN AND SATISFYING AND VERY INTERESTING. I LOVE THE COLORS AND THE PRACTICAL PART.

UNDERSTAND EVERYTHING THAT HAPPENS AROUND US

I LOVE BIOCHEMISTRY AND CHEMISTRY REACTION AS WELL AS PRACTICAL WORK IN LABS.

I LIKE TO MAKE EXPERIENCES TO UNDERSTAND THE INTERACTIONS BETWEEN THINGS

I WANT TO KNOW HOW WORLD WORKS, CHEMISTRY SEEMS ABOUT HOW EVERYTHING IS BUILT AND INTERACTS, IT IS ALSO BEAUTIFUL AND A BIT LIKE MAGIC.

I CHOSE CHEMISTRY BECAUSE I HAD A LOT OF FUN IN COLLEGE. IT'S AN ENDLESS WORLD OF POSSIBILITIES

BECAUSE I WANTED TO TEACH PEOPLE THAT CHEMISTRY CAN BE A FUN AND VERY INTERESTING SCIENCE

MAKE MEDICINE/TREATMENTS TO HELP PEOPLE IT'S COOL AND VERY USEFUL TO TACKLE HEALTH ISSUES

TO PLEASE MY DAD BECAUSE CHEMISTRY IS EVERYWERE. WE CAN STILL DISCOVER THINGS AND I LOVE ELECTRO-CHEMISTRY

I WANT TO WORK IN PERFUMES NEW DISCOVERIES, RESEARCH, CURIOSITY IT'S PRETTY SICK

I HAVE ALWAYS LOVED THE WAY YOU CAN UNDERSTAND HOW SOMETHING REACT WITH ONE ANOTHER, AND ALSO THE WAY IT CAN BE FORMED IN SO MANY WAYS

I LOVE SCIENCE AND MAKING EXPERIENCES, REACTIONS ARE SO INTERESTING I ONCE MADE GELATO WITH LIQUID AZOTE AND LOVED IT

BECAUSE I THINK THIS IS A WONDERFUL TOPIC, WITH THE EXPERIMENT IN THE LAB AND ALSO ALL THE POSSIBILIES THAT YOU CAN HAVE

BECAUSE I WANT TO COOK METH IT'S POETIC I WATCHED BREAKING BAD ばくれつ IT SEEMS COOL

TO TINKER

IT IS FASCINATING PERFUME BECAUSE IT WAS THE ONLY SECTION LEFT I LIKE CHEMISTRY AND I WANT TO DO RESEARCH

FOR THE LABORATORY PART PHARMA ORGANIC REACTIONS FOR THE FUN OF IT PERFUMERY AND FINE FRAGRANCES

IM CURIOUS

I'M VERY CURIOUS AND I LOVE TO COOK OPPURTUNITES I REALLY LIKE THE SUBJECT I LOVE BREAKING BAD BECAUSE OF MY MOTHER WHO WORKS IN THE PHARMA INDU

EXPERIMENT IT'S DIVERSE BREAKING BAD I DON'T WANT TO INDUSTRIAL CHEMISTRY

MOSTLY FOR THE LAB WORK. SEEMS FUN IT'S FUN! I LIKE IT FASCINATING REACTIONS THEIR IS REALLY FUN EXPERIMENT TO DO

I LOVE COOKING AND EXPERIENCES FASCINATING LARGE CHIMIE ORGANIQUE POSSIBILITIES, APPLICATION IN MANY FIELDS

DRUGS IT'S BEEN MY FAVOURITE SUBJECT SINCE I WAS YOUNG, ESPECIALLY ORGANIC CHEMISTRY

PAYS WELL IN SWITZERLAND AND FUN I ALSO LOVE TO COOK AND BAKE IT'S FUN IT WAS BETTER THAN THE OTHER CHOICES

JOBS OPPORTUNITIES I CHOOSE CHEMISTRY BECAUSE IT'S A SCIENCE CLOSE FROM NATURE. PASSION

BECAUSE I LIKE EXPERIMENTING THINGS I'M CURIOUS AND LOVE TO DISCOVER NEW SUBJECTS TO HELP THE WORLD WHILE DOING A THING THAT I LOVE

BECAUSE I LIKE UNDERSTANDING HOW THINGS FONCTION AND HOW THEY INTERACT I LIKE THE THOUGHT OF CREATING NEW THINGS

I USED TO LOVE MAKING SLIME SINCE I WAS A CHILD, MIXING THINGS AND SEEING WHAT I GET OUT OF IT GIVES ME JOY

I LIKED IT WHEN I HAD CHEMISTRY IN GYMNASE AND I WANTED TO PURSUE IT. I DONT KNOW

I HAVE AN INTEREST FOR PHARMACOLOGY I LOVE MAKING THINGS EXPLODE. LET HIM COOK

UNDERSTAND HOW THINGS WORKS AND HOW TO CREATE NEW THINGS IT'S THE ONLY SUBJECT THAT I'M REALLY INTERESTED IN

BECAUSE I LOVE WHEN U MIX TWO THINGS TOGETHER AND U GET SOME WEIRD SOLUTION BUT IT DOESN'T MATTER BECAUSE U HAD FUN.

ORGANIC CHEMISTRY, I LIKE TO EXPLORE EVERY ASPECT OF THE WORLD AND TO GATHER A LOT OF KNOWLEDGE ABOUT WHAT'S SURROUNDING ME

I WAS INTERESTED IN COOKING AND MOLECULAR CUISINE, AND I REALLY APPRECIATED CHEMISTRY, ESPECIALLY LABS IN HIGH SCHOOL

TO MAKE FUN POTIONS AND UNDERSTAND THINGS HAPPENING

BECAUSE I WORKED IN RESEARCH GROUPS AND THEY MADE ME WANT TO LEARN MORE.

I LOVED CHEMISTRY IN HIGH SCHOOL AND MY COUSIN STUDIED CHEMISTRY AT EPFL AND ENCOURAGED ME TO COME HERE

BECAUSE I'M INTERESTED TO DISCOVER THE MATTER THAT SURROUNDS ME SINCE I WAS A LITTLE CHILD !

I LOVE THE EXPERIMENT PART OF CHEMISTRY, DISCORVERING THINGS, CHANGING MATTER OR MAKING REACTIONS THEN UNDERSTANDING WHAT HAPPENED, THEN I LEARNED THAT THE SOCIAL PART OF THE EPFL SO I CAM

IT WAS THE ONLY SUBJECT I STUDIES OUTSIDE SCHOOL CLASSES, I TOOK SOME EXTRA CLASSES WITH A PROFESSOR AND I FELT IN LOVE WITH ORGANIC AND BIOCHEMISTRY, AND LATER EPFL

I ENJOYED IT DURING HIGH SCHOOL AND I HAVE FOUND A BIG INTEREST IN CHEMICAL REACTIONS

BC MAGIC, I LIKE THE IDEA OF WORKING IN THE LAD AND CREATING STUFF, ALSO COLORS

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

Be prepared: Quantum chemistry is weird (and wonderful!)

- **Example 1: Wave-particle duality**
- **What it means**: Particles like electrons and photons can behave both as particles and as waves.
- **Weirdness**: Imagine a tennis ball that sometimes acts like a solid object, but when you're not looking, it spreads out like a wave across the court!
- **Example**: The famous double-slit experiment, where particles passing through two slits create an interference pattern like waves, even when fired one .particle at a time

Be prepared: Quantum chemistry is weird (and wonderful!)

- **Example 2: Quantization of energy**
- **What it means**: Energy levels in quantum systems are discrete rather than continuous.
- **Weirdness**: In the macro world, you can climb a ramp and stop anywhere, but in the quantum world, it's like being forced to step only on specific, invisible rungs of a ladder.
- **Example**: Electrons in atoms can only exist at certain energy levels and have to "jump" between them, emitting or absorbing energy in the form of photons

Be prepared: Quantum chemistry is weird (and wonderful!)

- **Example 3: Heisenberg's Uncertainty Principle**
- **What it Means**: There's a fundamental limit to how precisely we can know both the position and momentum (speed and direction) of a particle at the same time. **The more accurately you know one, the less accurately you can know the other.**
- **Weirdness**: In the macroscopic world, you can easily measure both a car's position and speed without any issue. But in the quantum world, this is impossible. The act of measuring one property (like position) affects the other (like momentum), so you can never have perfect knowledge of both at the same time.
- **Example**: Imagine trying to track the exact location and speed of an electron in an atom. **If you shine light to observe the electron's position, the light itself disturbs the electron, making it impossible to measure its speed precisely.** The more you try to pin down its exact location, the more uncertain its speed becomes, and vice versa.

Early chemists

- Prepared glass, jewels, coins, ceramics, and, inevitably, weapons:

  Art, agriculture, & warfare

- 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)

Chemistry shapes the modern world

- **Steel**: industrial revolution
- Chemical industry: fertilizers, communication, transportation, enhanced materials:

  Polymers → *fabrics*

  Ultrapure silicon → *computer chips*

  Glass → *optical fibers*

  Renewable fuels

  *Tough & light alloys for **air travel***
- **Medicine** → higher life expectancy because of chemistry, genetic engineering
- **Climate change**

Chemistry is a science at three levels

- **Macroscopic**: Matter and transformations (a leaf turns orange.)
- **Microscopic**: Rearrangement 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.

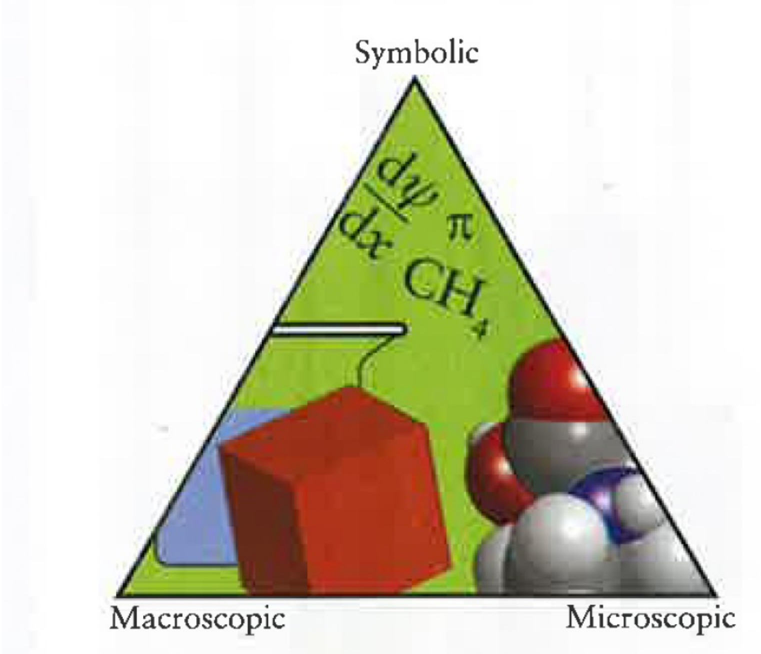


Figure 3

How science is done: The scientific method

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

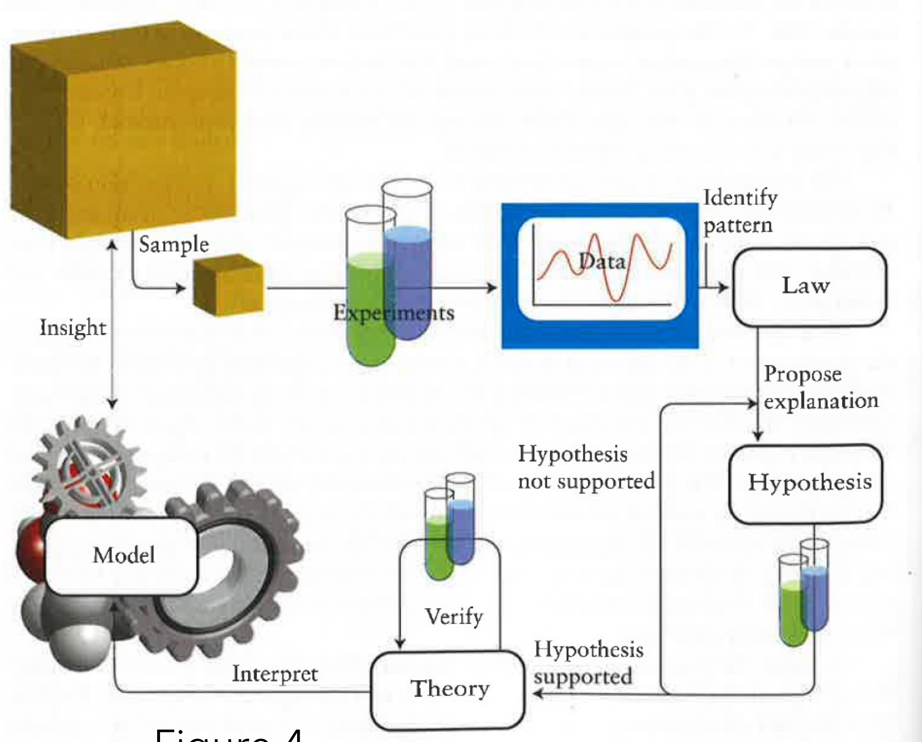


Figure 4

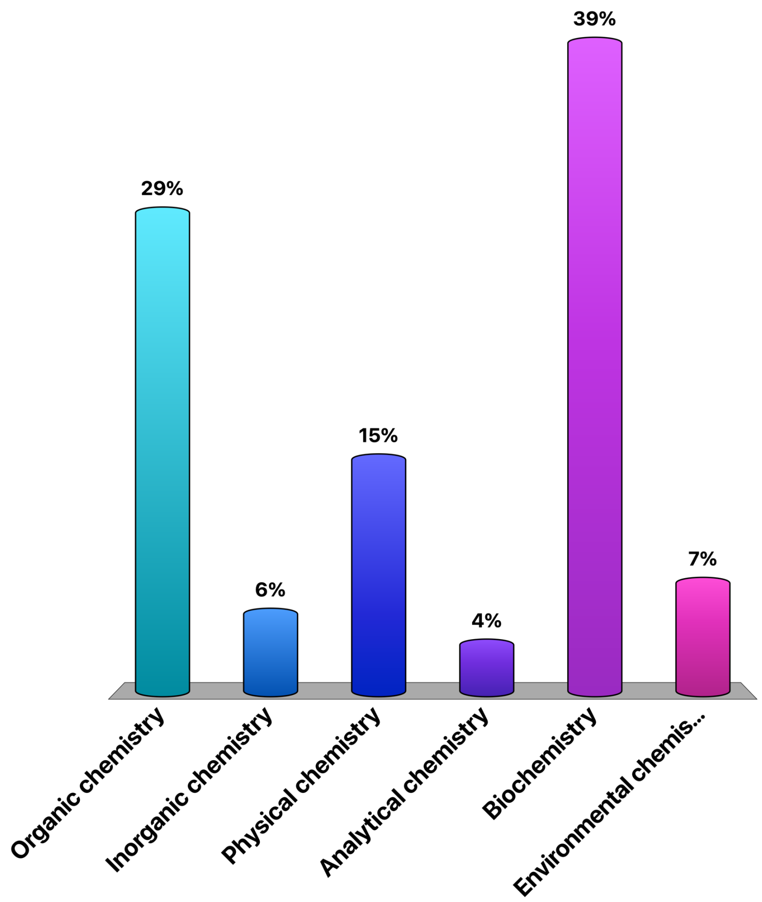
- **Law**: succinct summary of a wide range of observations
- **Hypothesis**: possible explanation of the law
- **Theory**: formal explanation of the law
- **Model**: a simplified version of the object of study that scientists can use to make predictions

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
F. Environmental chemistry



Fundamentals

Please review Fundamentals A and B in the textbook:

A: Matter and Energy

B: Elements and Atoms

Important definitions

- **Matter**: anything that has mass and takes up space
- **Substance**: single, pure form of matter
- States of matter:
  - *A **solid** is a form of matter that retains its shape and does not flow.*
  - *A **liquid** is a form of matter that has a well-defined surface; it takes the shape of the part of the container it occupies.*
  - *A **gas** is a fluid form of matter that fills any vessel containing it.*
- **Vapor** denotes the gaseous form of a substance that is normally a liquid or solid. For example, water exists as a solid (ice), liquid, and as vapor (steam).

Physical vs. chemical properties

- **A physical property** of a substance is a characteristic that can be observed or measured without changing the identity of a substance.
- *E.g. mass, temperature, melting point, hardness, color, state of matter, and density.*
- **A chemical property** refers to the ability of a substance to be changed into another substance.
- *E.g. a chemical property of hydrogen gas (H_2) is that it reacts with oxygen (O_2) to produce water (H_2O). Oxidation states, reactivity with acids or bases, electronegativity, radioactivity.*

Symbols and units

SI Base Units			
Base quantity		**Base unit**	
Name	**Typical symbol**	**Name**	**Symbol**
time	t	second	s
length	l, x, r, etc.	meter	m
mass	m	kilogram	kg
electric current	I, i	ampere	A
thermodynamic temperature	T	kelvin	K
amount of substance	n	mole	mol
luminous intensity	I_v	candela	cd

Source: NIST Special Publication 330:2019, Table 2.

Significant figures

- The number of significant figures in a numerical value is the number of digits that can be **justified by data**.
- When reporting the results of **multiplications and divisions**, identify the number of digits in the least precise value and retain that number of digits in the answer.
- When reporting the results of **additions and subtractions**, identify the quantity with the least number of digits following the decimal point and retain that number of digits in the answer.

Accuracy and precision

- **Precision** of a measurement is an indication of how close repeated measurements are to each other.
- **Accuracy** of a series of measurements is the closeness of their average value to the true value.

To remember:

Precision is how **Packed** the measurements are together (close to each other).

Accuracy is how accurate the measurements are to the **Actual value** (close to the true value).

Which case is precise but inaccurate?

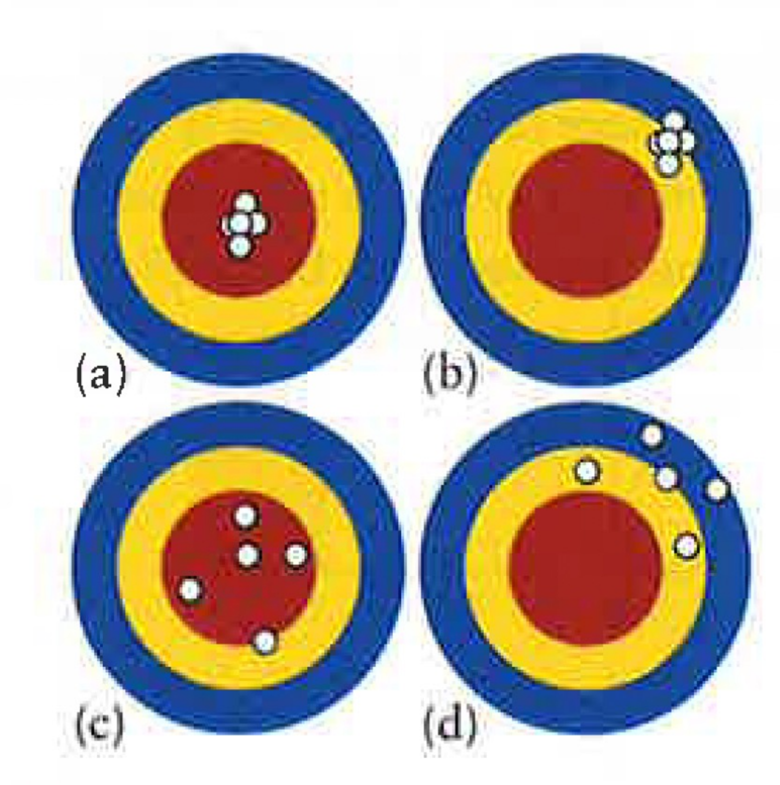
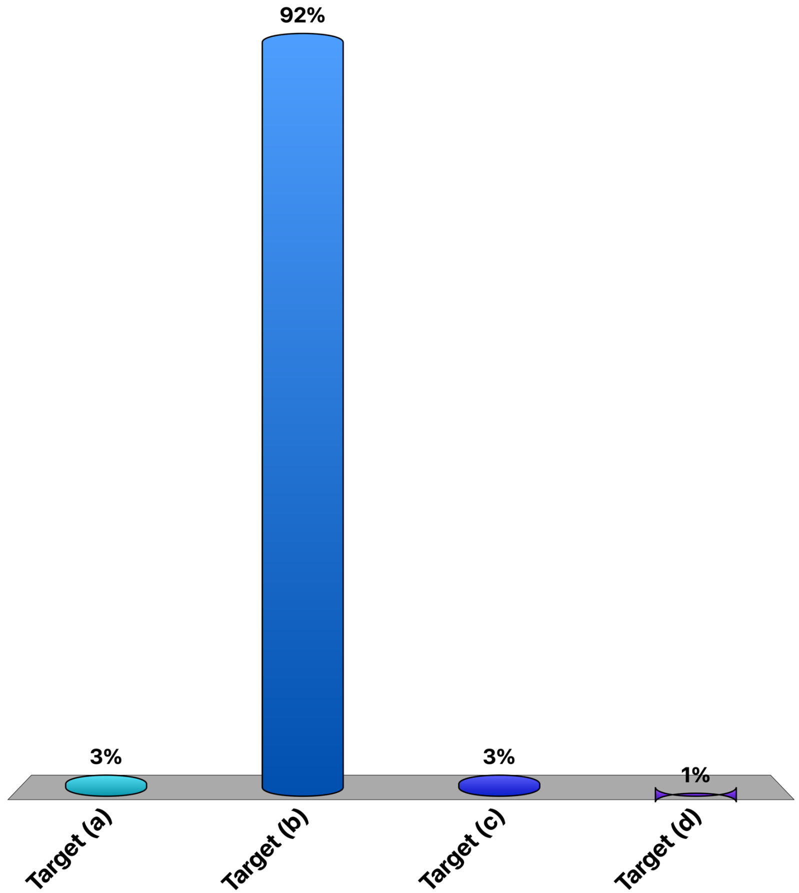


Figure A.3



Systematic vs. random error

- A **systematic error** is present in every one of a series of repeated measurements. Same sign and magnitude. E.g. lab scale that is not properly calibrated.
- A **random error** varies in both sign and magnitude and can average to zero over a series of measurements.

Speed vs. velocity

Speed, *v* (m/s): it describes how fast an object is moving but does not include any information about direction (**scalar** quantity)

Velocity: closely related to speed: rate and DIRECTION (**vector** quantity)

For example: A particle moving in a circle at a constant speed has a constantly changing velocity.

Acceleration, *a*: rate of change of velocity

For example: A particle is moving in a straight line at a constant speed is not accelerating (speed plus direction same).

BUT: a particle moving at a constant speed in a curved path accelerates because although its speed is constant, its velocity is changing (this is called **centripetal acceleration**).

Force

Force is an influence that changes motion of an object.

E.g. you exert force to open door or hit a ball with a baseball bat.

Newton's second law of motion: When an object experiences a force, it is accelerated in proportion to the force it experiences.

$$a = \frac{F}{m}$$

m: mass of body

Energy

Work is the process of moving an object against an opposing force:

Work done = force x distance

Units: 1 Nm = 1 J (equals the work of one human heart beat)

Energy: capacity to do work

e.g. energy is needed to do the work of raising a weight (book) to a given height or forcing an electric current through a circuit.

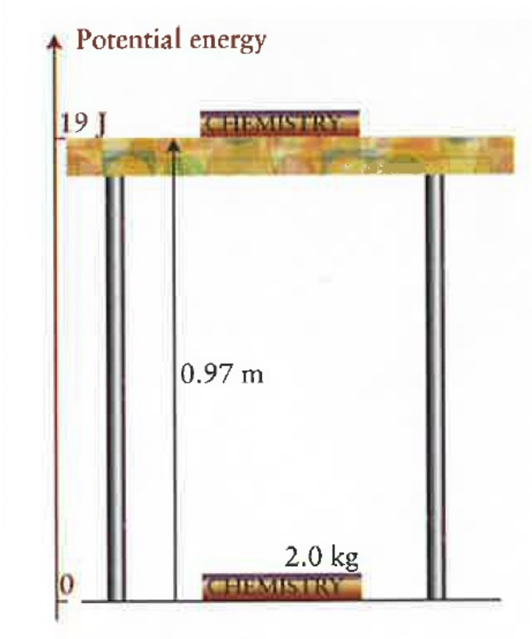


Figure A.5

Energy in chemistry

1. Kinetic energy, E_K, is the energy that a body possesses due to its motion. For a body of mass *m* traveling at a speed *v*, the kinetic energy is

$$E_k = \frac{1}{2}mv^2$$

2. Potential energy, E_P, of an object is the energy that it possesses on account of its position in a field of force. No single formula because E_P depends on the nature of the force it epxeriences. Two simple cases:

1) A body of mass *m* at a height *h* above the surface of the Earth has **a grativational potential energy**:

$$E_p = mgh$$

with *g*, acceleration of free fall ("acceleration of gravity") of 9.81 m s^{-2}

Energy in chemistry

2. Potential energy

2) **Coulomb potential energy** of a particle Q_1 at a distance r from another particle of charge Q_2 is proportional to the two charges and inversely proportional to the distance *r* between them:

$$E_P = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$$

$$\varepsilon_0: eletric\ constant\ (8.854\ x\ 10^{-12}\ J^{-1}C^2m^{-1})$$

Figure A.7: Coulomb potential energy of two opposite charges (red and green sphere), potential energy decreases as the charges approach each other.

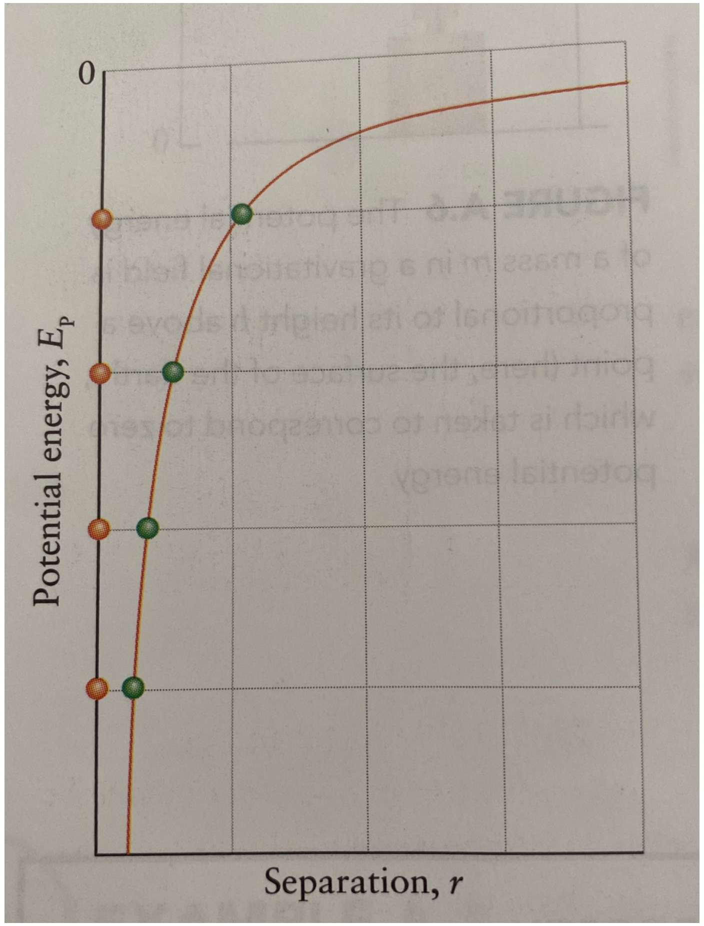


Figure A.7

Energy in chemistry

3. The electromagnetic energy is the energy of the electromagnetic field, such as the energy carried through space by radio waves, light waves, and X-rays.

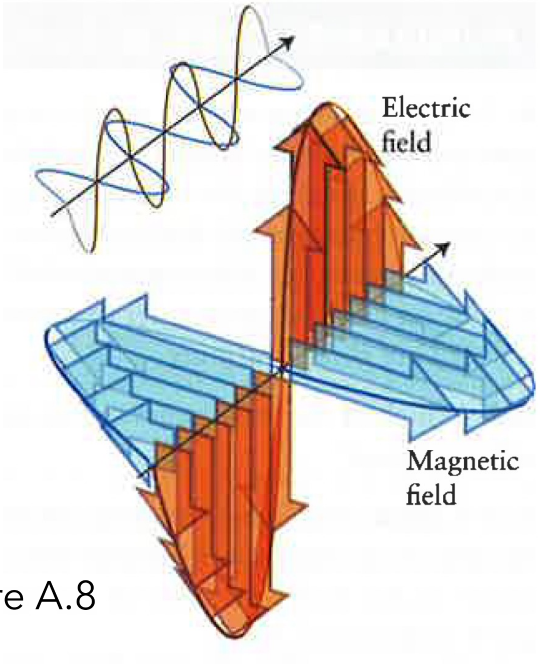


Figure A.8

Electromagnetic field is generated by **acceleration of charged particles**.

The field consists of **an oscillating electric field** and **oscillating magnetic field**.

The electric field affects charged particles whether they are moving or not.

The magnetic field only affects *moving* charged particles.

More in Topic 1A.

Energy in chemistry

The total energy, E, of a particle is the sum of its kinetic and potential energies:

$$E = E_k + E_p$$

E is **conserved** (constant) for a given, isolated system.

What happens when the ball hits the earth?

Ball is no longer isolated.

Energy dissipates as thermal motion.

Total energy of earth has increased by exactly the same amount as that lost by the ball.

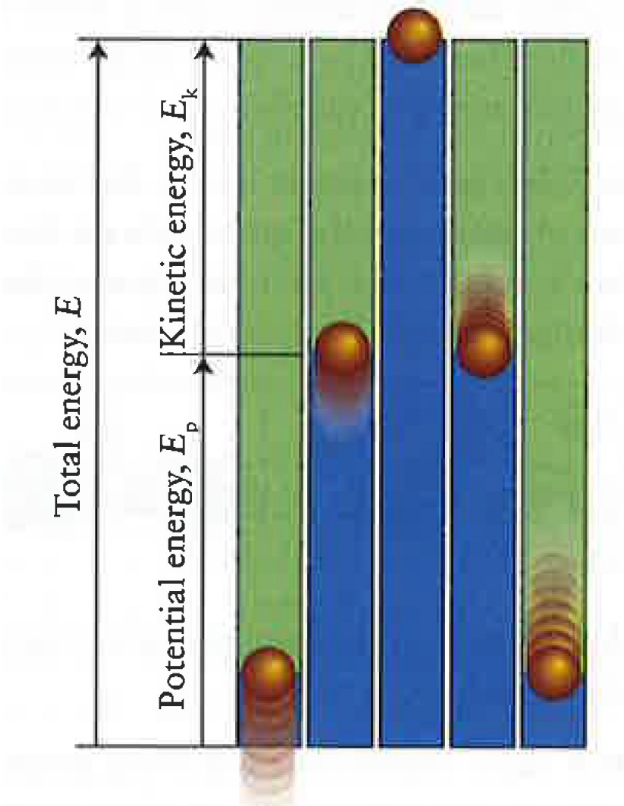
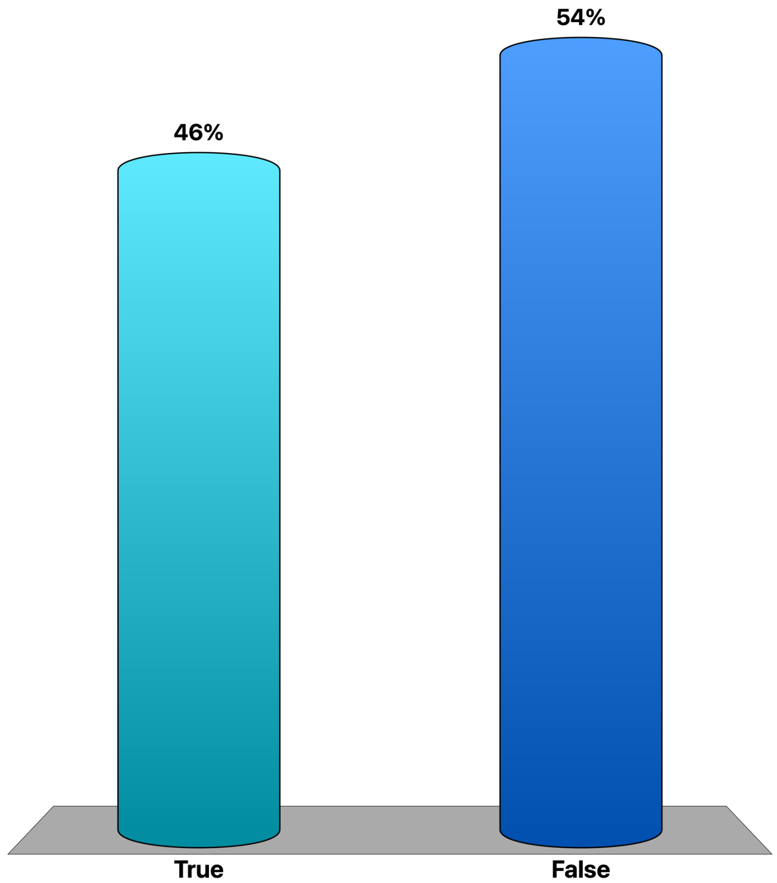


Figure A.9

Work and energy have the same units.

A. True

B. False



http://responseware.eu

Session ID: 454314

True.

Work and **energy** both have the same units, which are **joules (J)** in the International System of Units (SI).

Work is defined as the transfer of energy when a force is applied over a distance, and it's calculated using the formula:

Work = Force × Distance

Since force is measured in **newtons (N)** and distance in **meters (m)**, the unit of work becomes:

1 joule (J)=1 newton-meter=1 N·m

Energy (such as kinetic energy, potential energy, etc.) is also measured in **joules (J)**. For example, the formula for gravitational potential energy is:

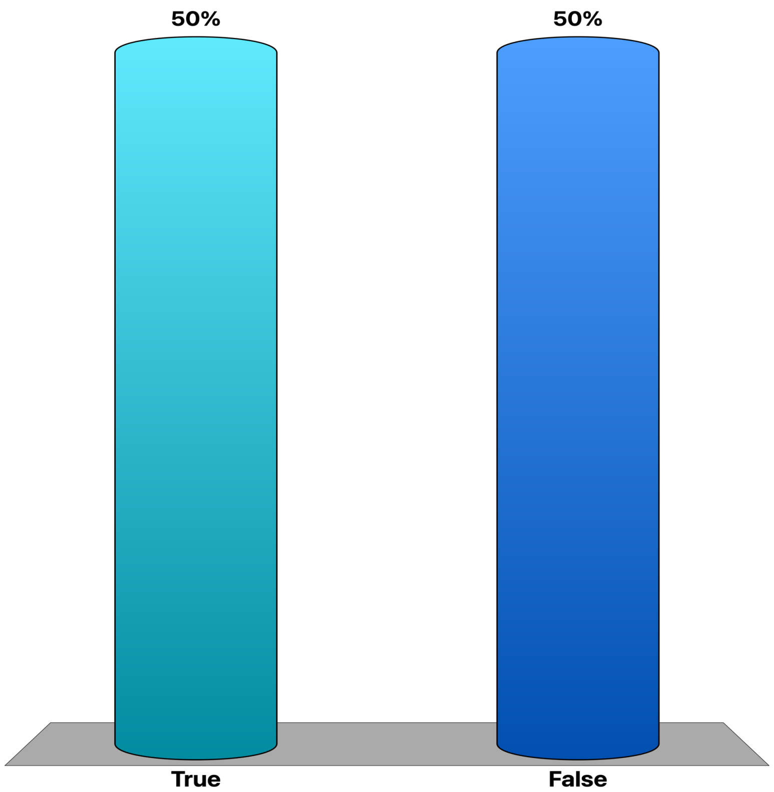
Potential Energy=mgh where mass is in kilograms (kg), gravity is in meters per second squared (m/s^2), and height is in meters (m), resulting in joules.

Thus, both work and energy are measured in **joules**, which is a way of quantifying the amount of energy transferred or the energy stored in a system.

According to Newton's second law of motion, an object will always accelerate, even if no force is applied to it.

A. True

B. False



http://responseware.eu

Session ID: 454314

False.

- According to **Newton's first law of motion** (the law of inertia), an object will remain at rest or in uniform motion (constant velocity) unless acted upon by an external force. In other words, if **no force** is applied to an object, it will not accelerate—it will either stay at rest or continue moving in a straight line at constant speed.
- **Newton's second law** further clarifies this with the equation:
- F=ma
- **F** is the net force,
- **m** is the mass,
- **a** is the acceleration.
- If **no force** is applied, then F= and since m is constant, this means a=0, so the object will not accelerate.
- Thus, an object **only accelerates when a net force** is applied to it. If there is no force, there is no change in motion (no acceleration).

The skills you have mastered are the ability to

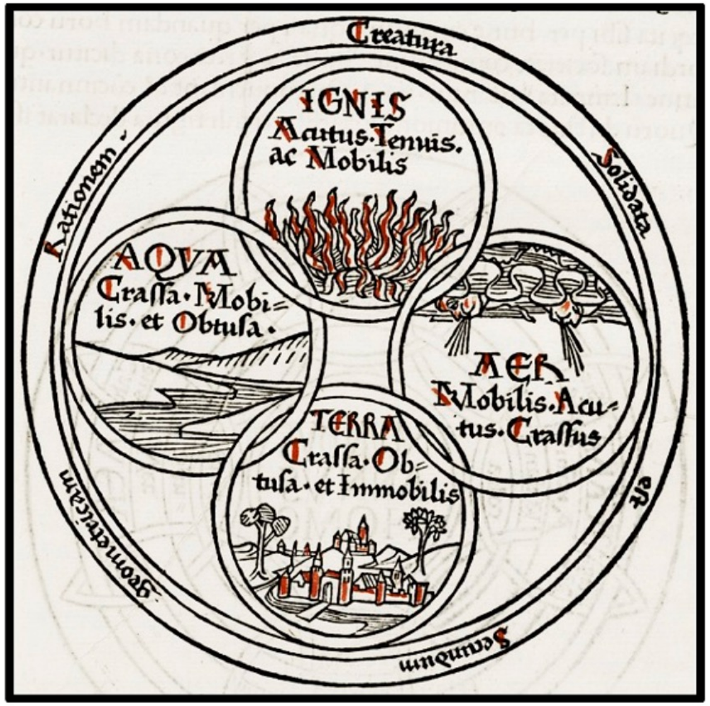
- ❑ Identify properties as physical or chemical.
- ❑ Convert between units.
- ❑ Calculate the kinetic energy of an object.
- ❑ Calculate the gravitational potential energy of an object.
- ❑ Express how the Coulomb potential energy depends on electric charge.

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.

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 Palton

- 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

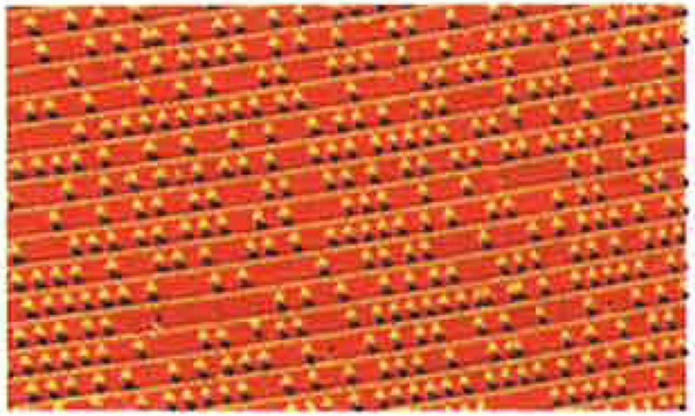


Figure B.3

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 x 10^{-27} kg

m_C = 1.99 x 10^{-26} kg

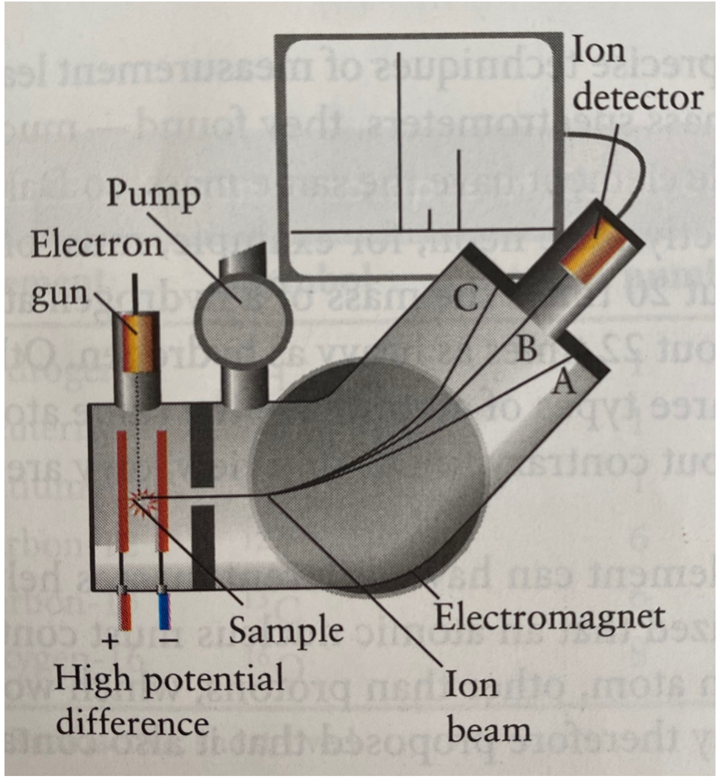


Figure B.5

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 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"

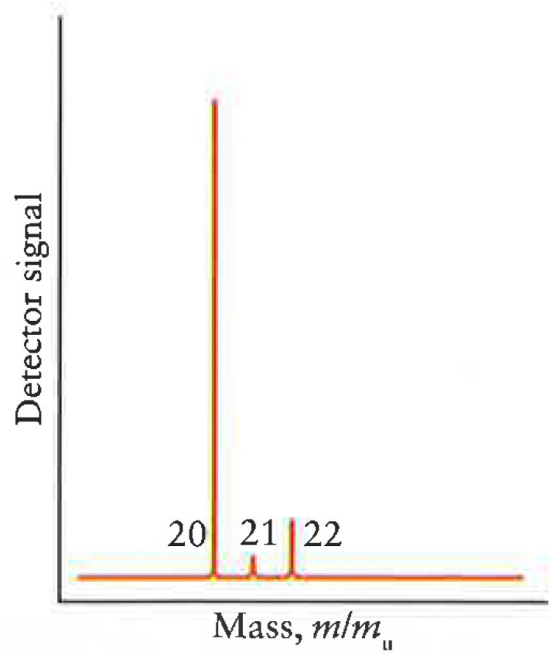


Figure B.6

Isotopes and mass number

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

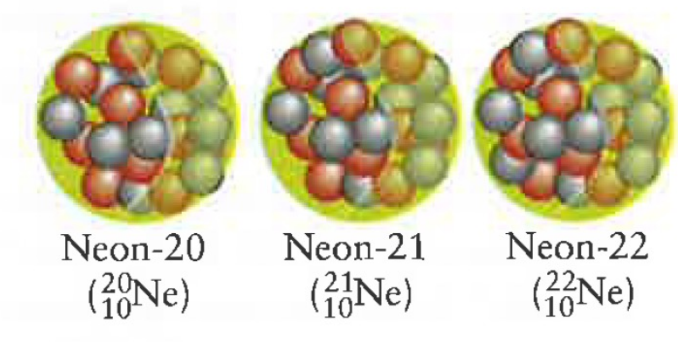


Figure B.7

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

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

Isotopes and mass number

TABLE B.2 Some Isotopes of Common Elements

Element	Symbol	Atomic number, Z	Mass number, A	Abundance/%
hydrogen	^{1}H	1	1	99.985
deuterium	^{2}H or D	1	2	0.015
tritium	^{3}H or T	1	3	—*
carbon-12	^{12}C	6	12	98.90
carbon-13	^{13}C	6	13	1.10
oxygen-16	^{16}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 quantitites on earth

The periodic table

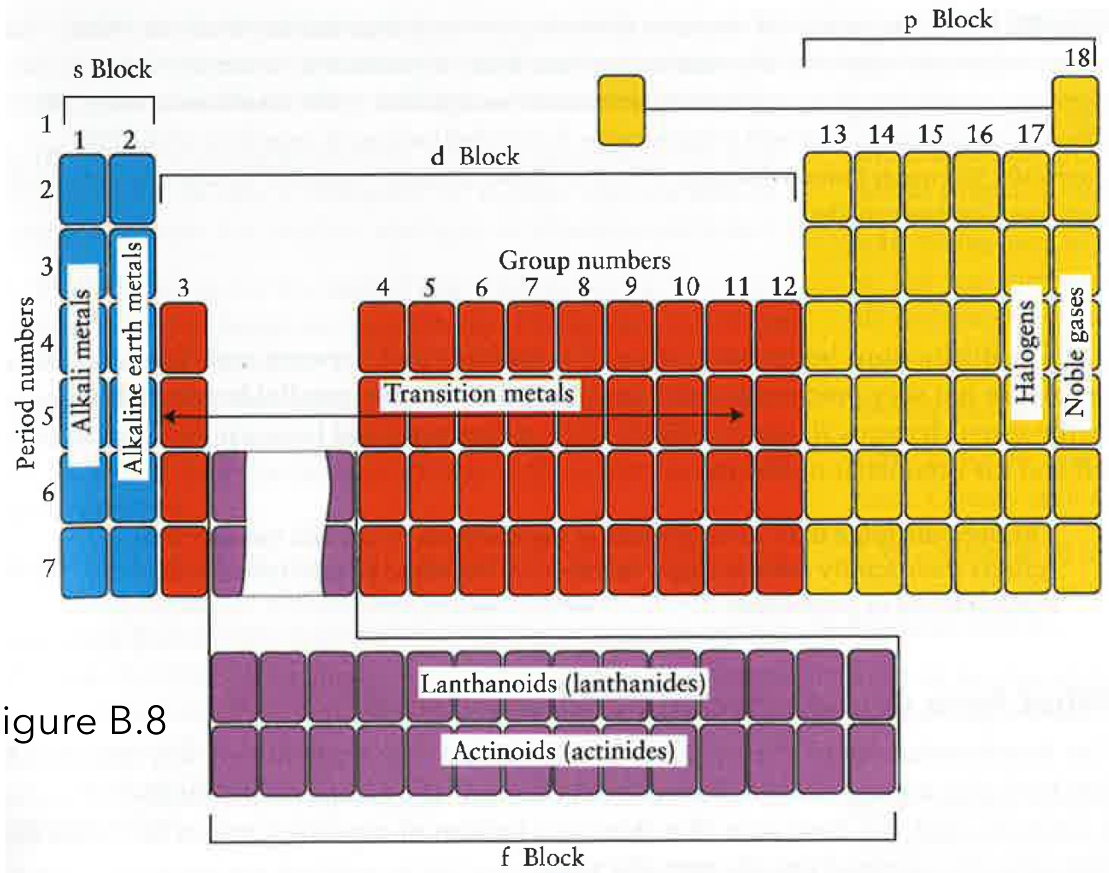


Figure B.8

- 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 Topid 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

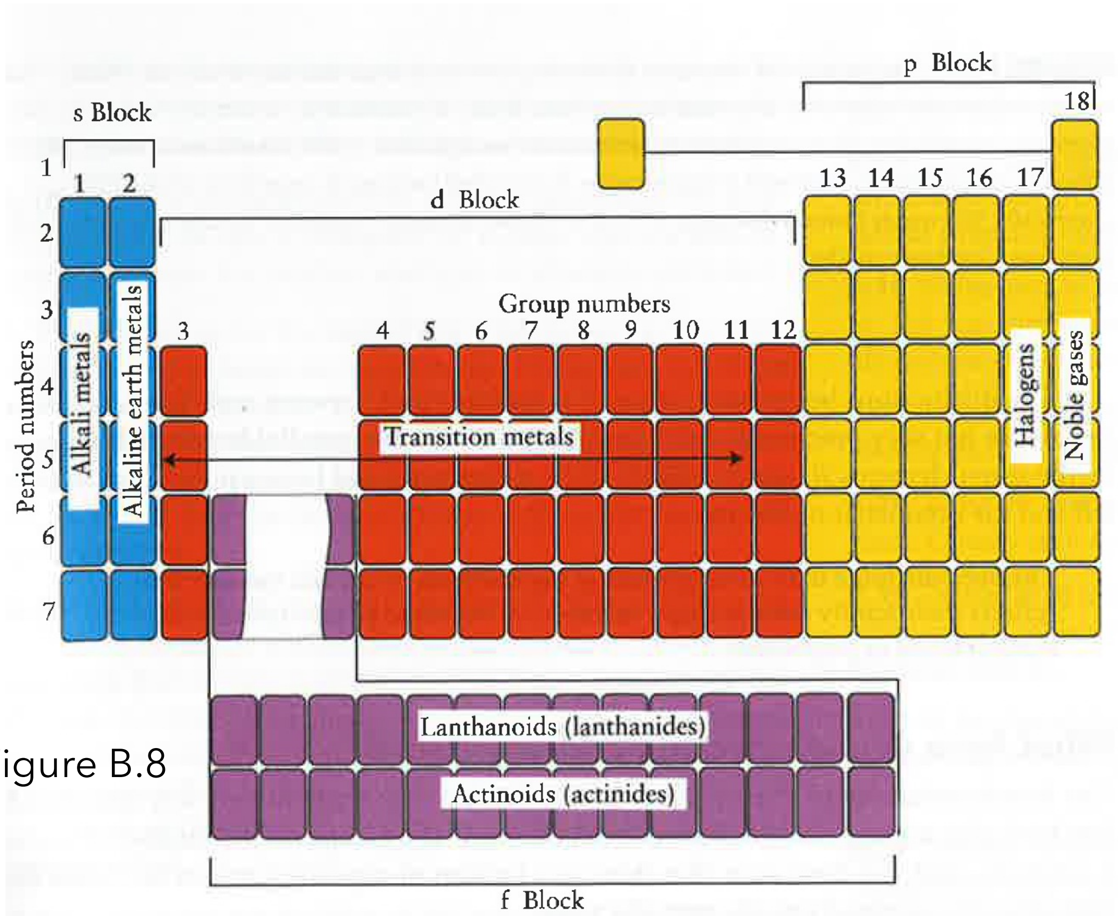


Figure B.8

- 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.

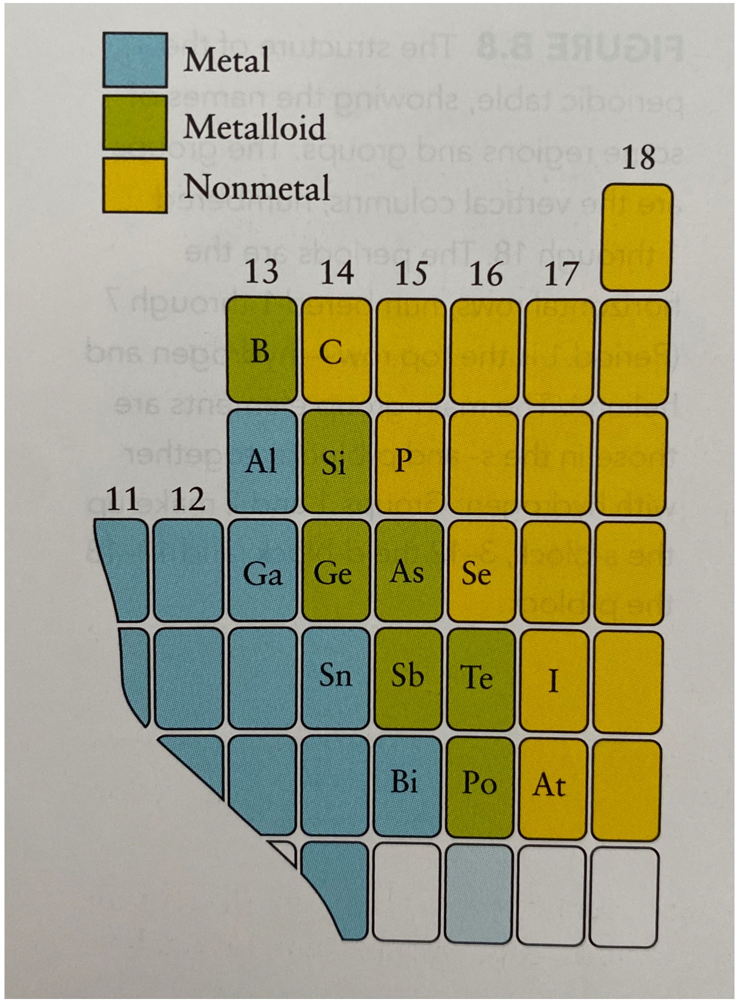


Figure B.10

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: Work is motion against an opposing force. Energy is the capacity to do work. Kinetic energy results from motion, potential energy from position. An electromagnetic field carries energy through space.

Preview Chapter 1 (Focus 1: Atoms)