APS110H1f2024 - Sept 4 2024

August 30, 2024 10:26 AM

Introductory day - APS110 Intro Chemistry and Materials Science

- **Section 3** - Prof Timothy P Bender - tim.bender@utoronto.ca - 'inbox' on Quercus

- **Land Acknowledgment**

I would like to acknowledge the land on which the University of Toronto operates. For thousands of years it has been the traditional land of the Huron-Wendat, the Seneca, and most recently, the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and I am grateful to have the opportunity to work on this land.

- The world is going through some challenging times currently. I hope that as you gain the specialized knowledge from this and your other courses you'll always consider how you can apply it to improve society and the quality of life for everyone on the earth.

... slides from First Year Dean's office

Introduction

September 3, 2024 10:26 AM

metal

polymer / rubber

metal

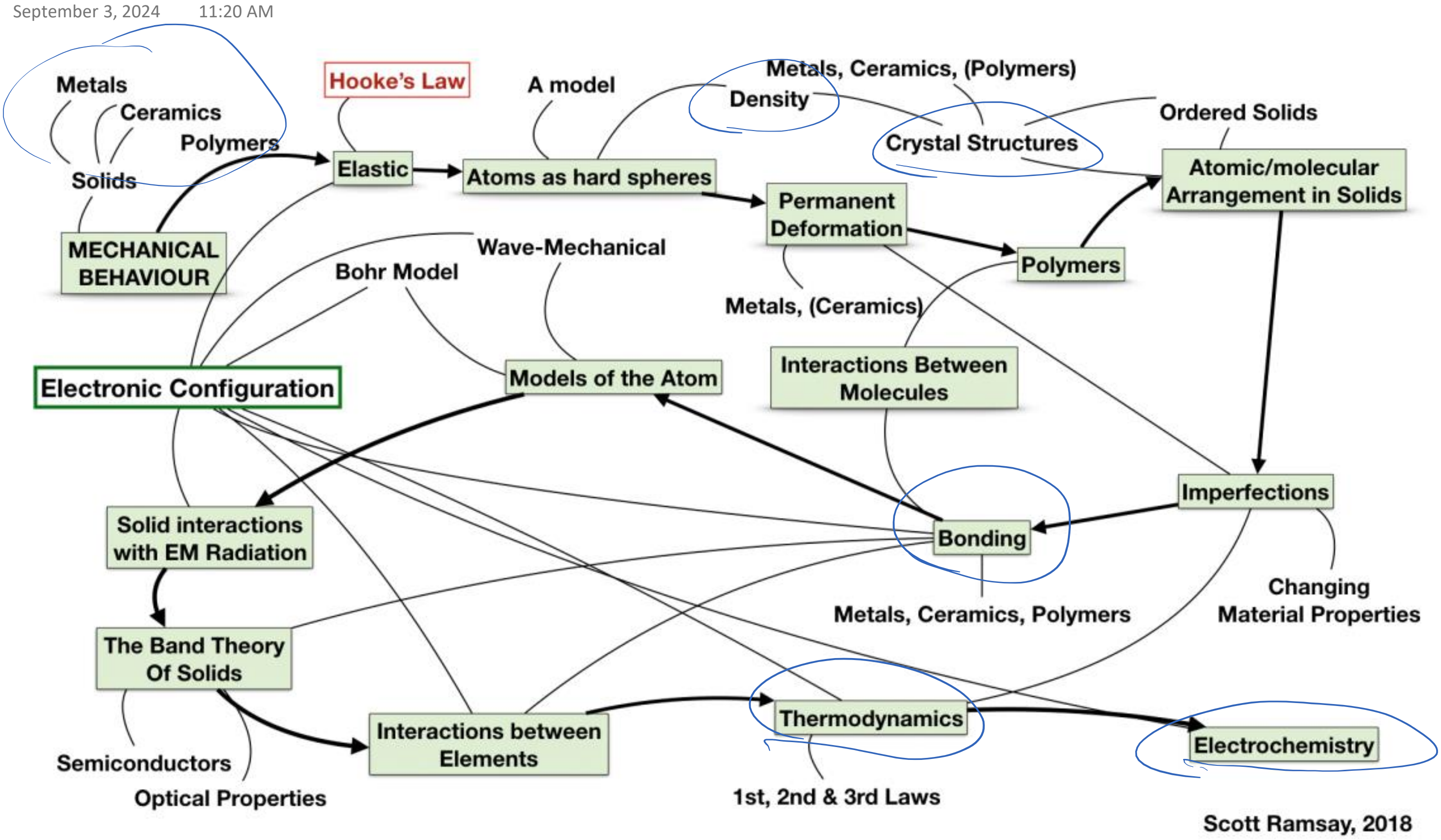
plastic

mineral engineer
chemical engineer → material engineers

civil engineer
mechanical engineer
electrical engineer / comp engineer.

Introduction 2

September 3, 2024 11:20 AM



Syllabus

September 3, 2024 10:21 AM

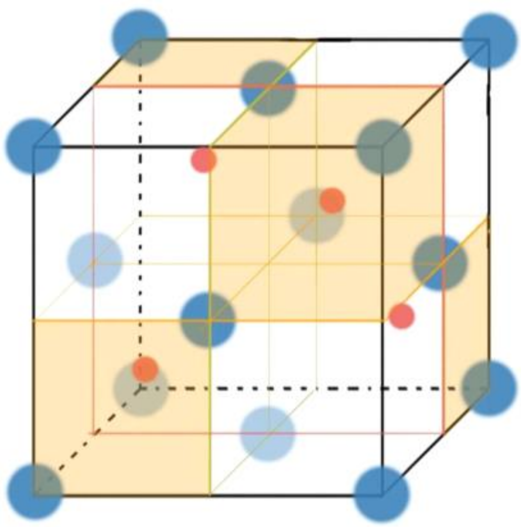
Course Syllabus for APS110/164 - Engineering Chemistry and Materials Science

Prof Timothy P. Bender **Prof Frank Gu**

Tim Bender and Frank Gu
Department of Chemical Engineering

Scott Ramsay **Prof Scott Ramsay**
Department of Materials Science & Engineering

Fall 2024



Contents

1 Land Acknowledgment

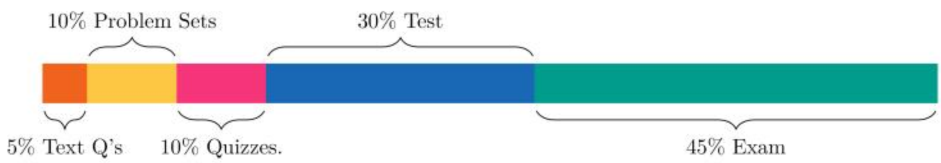
It is important to acknowledge the land that the University of Toronto itself is situated on. Therefore, we would like to acknowledge this land on which the University of Toronto operates. For thousands of years it has been the traditional land of the Huron-Wendat, the Seneca, and most recently, the Mississaugas of the Credit River. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.

2 Who is going to teach you

Prof. Tim Bender, PhD | tim.bender@utoronto.ca | LEC0103
Prof. Frank Gu, PhD, PEng | f.gu@utoronto.ca | LEC0102
Prof. Scott Ramsay, PhD, PEng | scott.ramsay@utoronto.ca | LEC0101

3 Mark Breakdown

The final grade that you earn in this course will be distributed across several items, as shown here.



- **Online Textbook Questions**
  These are completed online through the TopHat textbook.

- **Problem Sets**
  These will be posted on Quercus at least one week prior to the due date and your answers must be uploaded to Quercus as a single PDF document. You may work together with classmates on these, but you must not copy one another directly.

- **Online Quercus Quizzes**
  These will be completed on Quercus as timed 30 minute quizzes. The quiz will be available for a 24 hour period on the posted date, however once you begin you will only have one 30 minute attempt at the quiz.

- **Term Test**
  The test will be in person and follow the same format as previous tests, typically 10 - 15 MCQ followed by 4-5 short answer questions. Typically the time to complete the test is one hour.

- **Final Exam**
  This is run during the final exam period, in person. It follows the same format as in previous years and is 2.5 hours in duration.

4 Course Level Learning Outcomes

These are the high level learning objectives. Be sure to familiarize yourself with the detailed learning objectives for this course. By the end of this course, students should be able to:

1. Articulate at least one logical characterization scheme for matter
2. Describe the uniaxial mechanical behaviour of metals, ceramics, and polymers
3. Describe the elastic behaviour of matter under shear loading
4. Distinguish between crystalline and non-crystalline matter in terms of long-range and short-range order
5. Explain and perform basic calculations involving the most common crystal structures of matter
6. Describe the generalized mechanical behaviour of plastic, elastomeric, and brittle polymers in uniaxial tension
7. Describe the mechanisms for elastic and permanent deformation in metals, ceramics, and polymers
8. Rationlize the optical and electrical behaviour of matter in terms of the Band Theory of solids

9. Explain, compare, and contrast the primary bonds as well as secondary bonds
10. Explain the zeroth, first, second, and third laws of Thermodynamics
11. Descibe the spntaneity of a process in terms of the change in entropy
12. Analyze and interpret a binary phase diagram

5 What you'll learn in this course

This course is structured around the principle of structure-property relationship. This relationship refers to an understanding of the microstructure of a solid, that is, the nature of the bonds between atoms and the spatial arrangement of atoms, which permits the explanation of observed behaviour. Observed materials behaviour includes mechanical, electrical, magnetic, optical, and corrosive behaviour. Topics covered in this course include: structure of the atom, models of the atom, electronic configuration, the electromagnetic spectrum, band theory, atomic bonding, optical transparency of solids, molecular bonding, hybridized orbitals, crystal systems, imperfections in solids, materials thermodynamics, free energy, phase equilibrium, and chemical equilibrium.

5.1 How all of that fits into this course

In the detailed learning objective/lecture schedule provided on Quercus you'll find a chronological listing of the topics that will be covered in this course. You'll notice that the topical sections seem to jump around a bit. Good observation! This is because there are so many interrelated concepts in this course (and with other courses) and we will move into new topics as our level of understanding grows and we encounter new unanswered questions. As we build increasingly detailed levels of understanding we'll be able to return to older topics with a new appreciation. Beautiful.

You will only be assessed on what is covered in the learning objectives.

6 What you should know before this course

We will assume that you have already learned some basic topics. Some of these topics are important enough that I will cover them again, however most will not and so if you are a little rusty on any of them you will want to review them. I am happy to suggest helpful resources if needed.

- The basic structure of the atom (protons, neutrons, electrons, atomic number)
- The periodic table
- Hooke's Law as applied to springs (F=Kx)
- Proficiency with arithmetic and trigonometry
- Proficiency with basic mathematical functions including the exponential function and the logarithmic function
- The Cartesian coordinate system

7 Things to help you succeed

7.1 Textbooks that you'll find useful

Required Textbook
We'll be using an online textbook, hosted by Top Hat. You'll need to purchase the online textbook and enroll in the course using the join code indicated on Quercus.

NOTE: you should only be charged $37.80 plus tax. Do not pay more than this. If Top Hat asks you for more than this, please let me know.

Other Texts An excellent textbook that you may want to refer to if you are thirsty for more information or just need another perspective on a topic is *Fundamentals of Materials Science & Engineering*, 4th or 5th Edition, by William D. Callister, Jr., John Wiley & Sons, Inc.

Callister provides excellent coverage of nearly all of the topics in this course, however, when we cover thermodynamics and chemical equilibrium you may need more than Callister has to offer.

For the thermodynamics section, please refer to the following freely available text on the Open Textbook Library:

- Entire Text: General Chemistry: Principles, Patterns, and Applications
- Direct link to thermodynamics chapter.
- Direct link to chemical equilibrium chapter.

7.2 Videos

All of the lectures in this course will be made available through Prof. Ramsay's YouTube channel along with short videos on all of the topics.

8 Other important things that you should know

8.1 Communication with instructors

You may contact the instructors via email and we will do our best to respond in a timely fashion, however, we do receive a high volume of emails and occasionally will unintentionally overlook an email. If you do not receive a response from either of us within 12 - 24 hours or so, please email again.

We also encourage you to post questions on the course discussion board where your classmates will then also be able to benefit from the responses.

Please review discussion postings before posting your own to avoid redundant topics.

8.2 Deadlines

A deduction of 20% of the total possible points on an assignment will be awarded for each day that an assignment is late, beginning at one minute after the deadline and again for every 24 hour period thereafter.

9 Mental Health and Wellness

As a university student, you may experience a range of health and/or mental health issues that may result in significant barriers to achieving your personal and academic goals. The University of Toronto offers a wide range of free and confidential services and programs that may be able to assist you. We encourage you to seek out these resources early and often.

- Student Life Website
- Health and Wellness Website

If, at any point during the year, you find yourself feeling distressed and in need of more immediate support, visit the Feeling Distressed Webpage: http://www.studentlife.utoronto.ca/feeling-distressed for more campus resources.

Off campus, immediate help is available 24/7 through Good2Talk, a post-secondary student helpline at 1-866-925-5454.

All students in the Faculty of Engineering have an Academic Advisor who can advise on academic and personal matters. You can find your department's Academic Advisor here:
http://undergrad.engineering.utoronto.ca/advising-support-services/academic-advising/

10 Institutional policies and support

10.1 ACADEMIC INTEGRITY

Academic integrity is essential to the pursuit of learning and scholarship in a university, and to ensuring that a degree from the University of Toronto is a strong signal of each student's individual academic achievement. As a result, the University treats cases of cheating and plagiarism very seriously. The University of Toronto's Code of Behaviour on Academic Matters www.governingcouncil.utoronto.ca/policies/behaveac.htm) outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences. Potential offences include, but are not limited to:

In papers and assignments:

1. Using someone else's ideas or words without appropriate acknowledgement.
2. Submitting your own work in more than one course without the permission of the instructor.
3. Making up sources or facts.
4. Obtaining or providing unauthorized assistance on any assignment.

On tests and exams:

1. Using or possessing unauthorized aids.
2. Looking at someone else's answers during an exam or test.
3. Misrepresenting your identity.

In academic work:

1. Falsifying institutional documents or grades.
2. Falsifying or altering any documentation required by the University.

All suspected cases of academic dishonesty will be investigated following procedures outlined in the Code of Behaviour on Academic Matters. If you have questions or concerns about what constitutes appropriate academic behaviour or appropriate research and citation methods, you are expected to seek out additional information on academic integrity from your instructor or from other institutional resources. Please also refer to: www.utoronto.ca/academicintegrity/resourcesforstudents.html.

Normally, students will be required to submit their course essays to the University's plagiarism detection tool for a review of textual similarity and detection of possible plagiarism. In doing so, students will allow their essays to be included as source documents in the tool's reference database, where they will be used solely for the purpose of detecting plagiarism. The terms that apply to the University's use of this tool are described on the Centre for Teaching Support & Innovation web site (https://uoft.me/pdt-faq).

10.2 Inclusion

All students, staff, and faculty at the University of Toronto have a right to learn, work and create in a welcoming, respectful, inclusive and safe environment. In this class we are all responsible for our language, actions and interactions. Discriminatory speech or actions of any kind will not be permitted, and do not align with the values of our Faculty. As a class we will support each other's learning by creating an inclusive learning environment, one which is based on mutual respect for the dignity and worth of every person.

If you experience or witness any form of discrimination, please reach out to the Engineering Equity Diversity & Inclusion Action Group online, an academic advisor, a U of T Equity Office, or any FASE faculty or staff member that you feel comfortable approaching.

10.3 Accessibility needs

Students with diverse learning styles and needs are welcome in this course. Please feel free to approach me or contact Accessibility Services (accessibility.services@utoronto.ca) so we can assist you in achieving academic success in this course. If you require accommodations for a disability, or have any accessibility concerns about the course, the classroom or course materials, please contact Accessibility Services as soon as possible. Services and support The following are some important links to help you with academic and/or technical service and support

- General student services and resources at Student Life
- Full library service through University of Toronto Libraries
- Resources on conducting online research through University Libraries Research
- Resources on academic support from the Academic Success Centre
- Learner support at the Writing Centre
- Information about Accessibility Services
- Information for Technical Support/Blackboard Support (Portal Info)

10.4 Copyright

If a student wishes to copy or reproduce lecture presentations, course notes or other similar materials provided by instructors, he or she must obtain the instructor's written consent beforehand. Otherwise all such reproduction is an infringement of copyright and is absolutely prohibited.

10.5 Recordings of online sessions

This course, including your participation, will be recorded on video and will be available to students in the course for viewing remotely and after each session. Course videos and materials belong to your instructor, the University, and/or other source depending on the specific facts of each situation, and are protected by copyright. In this course, you are permitted to download session videos and materials for your own academic use, but you should not copy, share, or use them for any other purpose without the explicit permission of the instructor. For questions about recording and use of videos in which you appear please contact your instructor.

Eng Sci -

Track One -

CHE -

MSE -

Civ -

Min -

MEC -

ECE -

Introduction 3

September 3, 2024 12:45 PM

Rough plan for tutorials is:

Short review (<10 min)

Mock quiz (~30 min, self-graded)

Problem solving with classmates/TA (~3 problems presented by TA)

APS110H1f2024 - Sept 6 2024

September 3, 2024 12:52 PM

Metals → 0 states | 0 states | 0 states | 0 states
Cu , Au , Fe , Al 0 states
copper gold iron aluminum

Ceramics → glasses, concrete, etc Cu^{2+} O^{2-}

Al_2O_3 SiO_2 CuO TiO_2 Ti^{4+} O^{2-}

$2 \times 3^+ + 2^- \times 3 = 0$ → Si^{4+} O^{2-}

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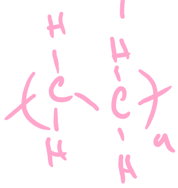
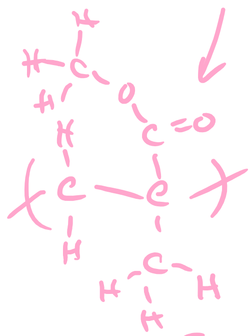
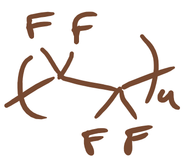
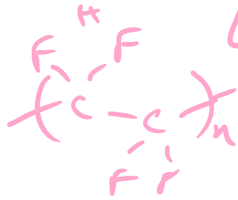
not salts = $NaCl_2$ i.e. here is a salt - above are not 'salts'...

CuO Cu^{2+} O^{2-}
cation anion

Polymers → poly(ethylene)  "organic" based on carbon

 ← don't draw like this

plexiglas  ← 

Teflon
poly tetrafluoro ethylene  

Kelvin - K Celsius - °C

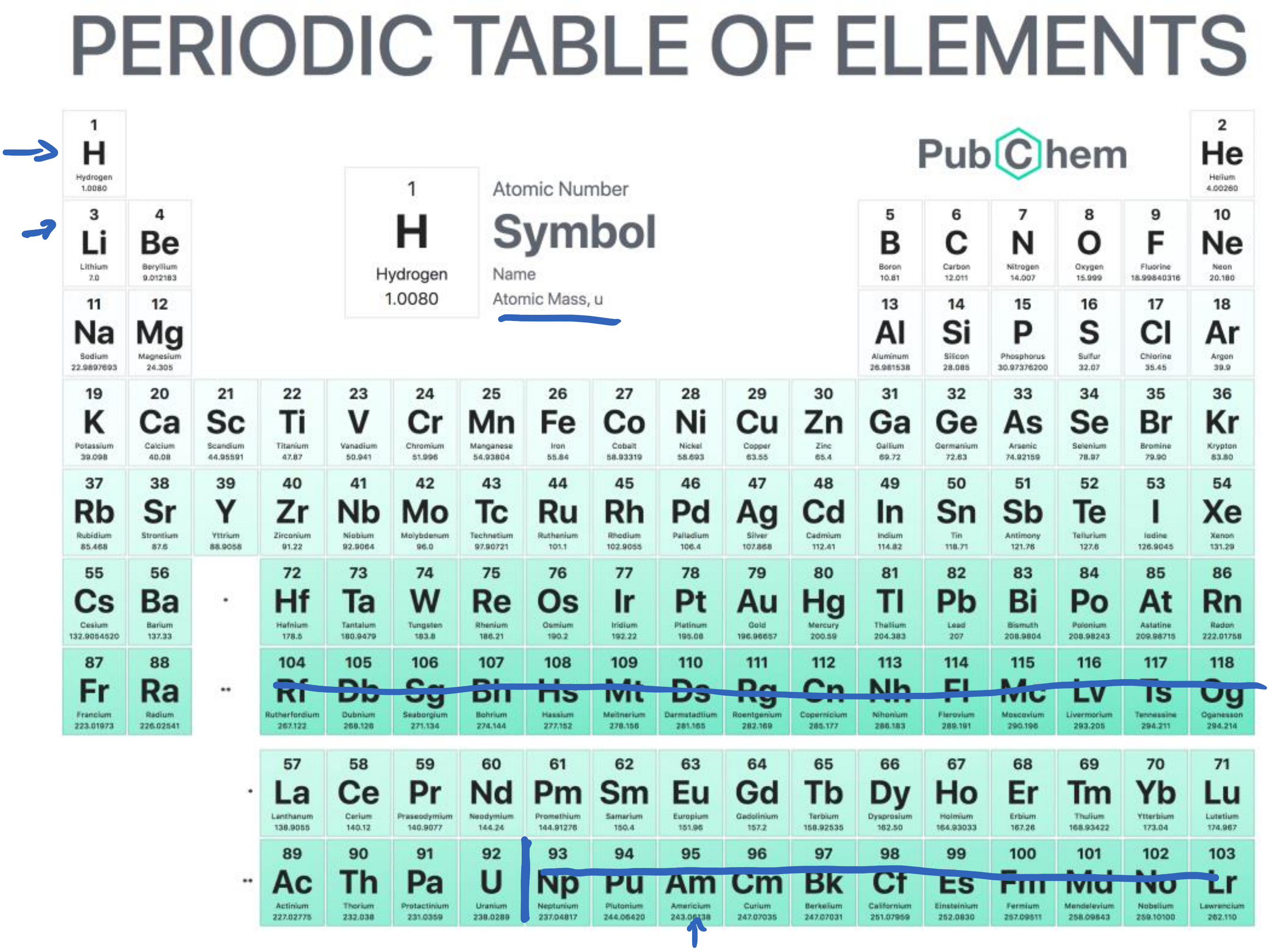
$0K = -273.15°C$ $100°C = 373.15K$

water
boiling point

Periodic table - atom mass

September 5, 2024 2:21 PM

https://pubchem.ncbi.nlm.nih.gov/



Periodic table - atom radius

September 5, 2024   2:22 PM

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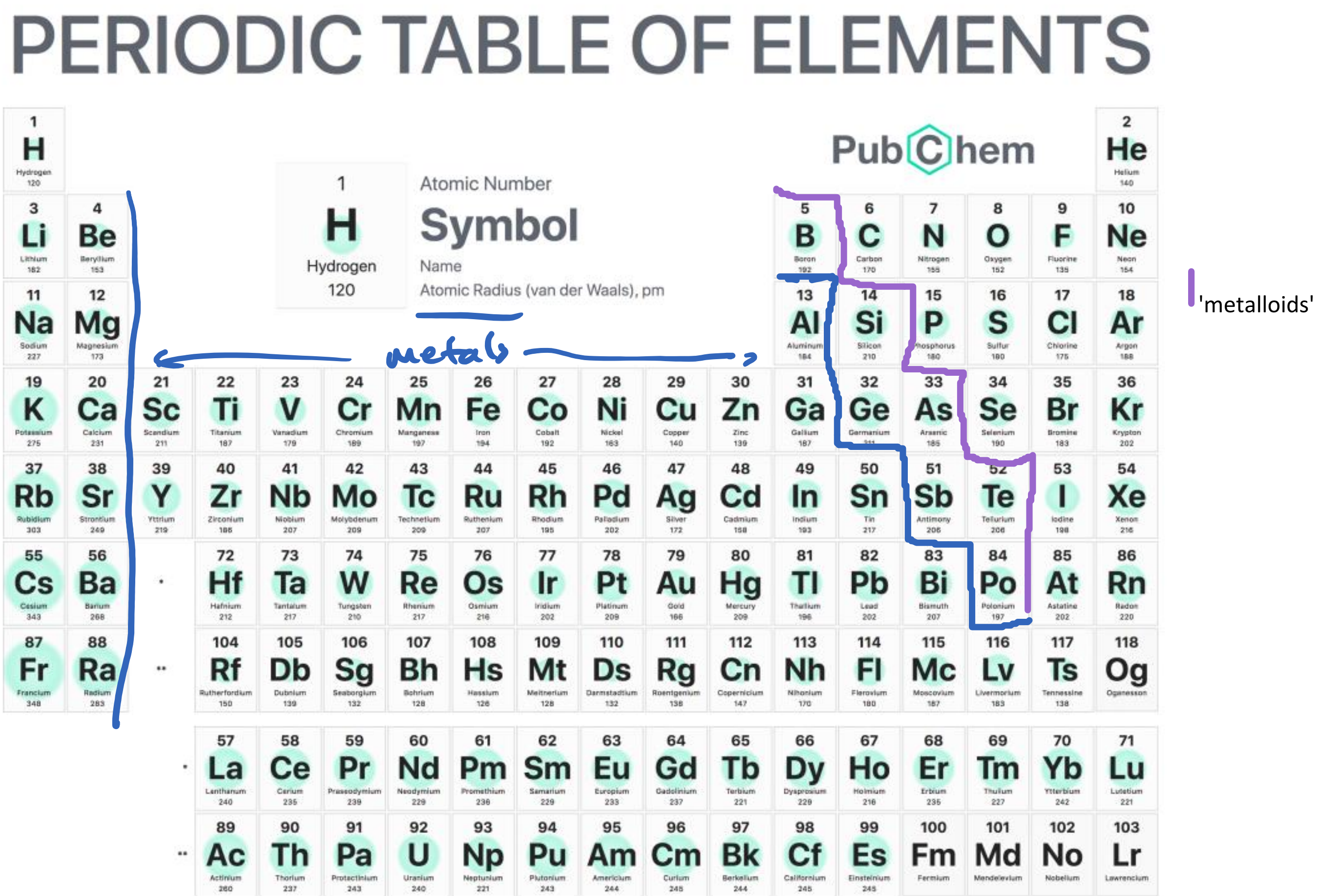
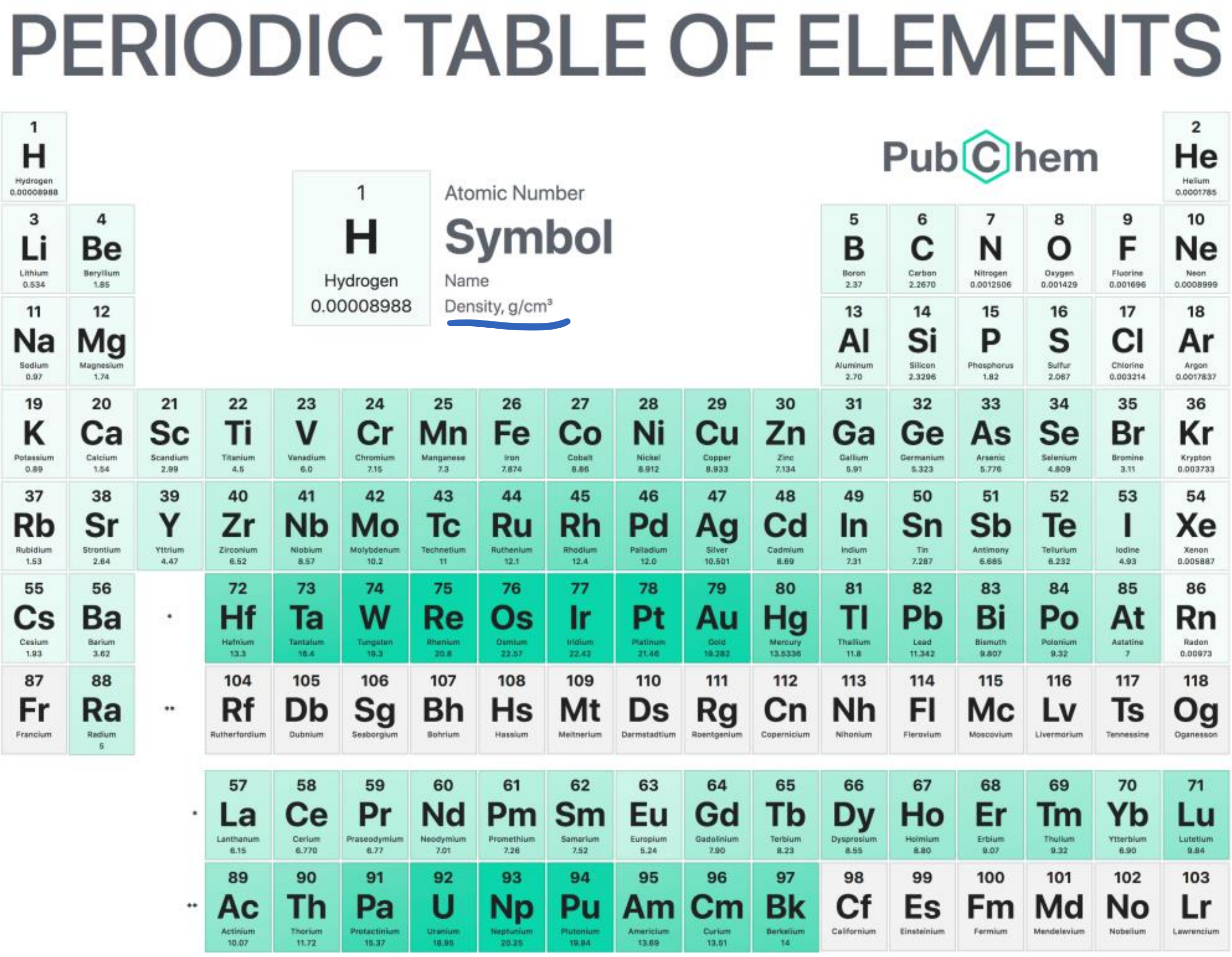


Periodic table - density

September 6, 2024 8:11 AM

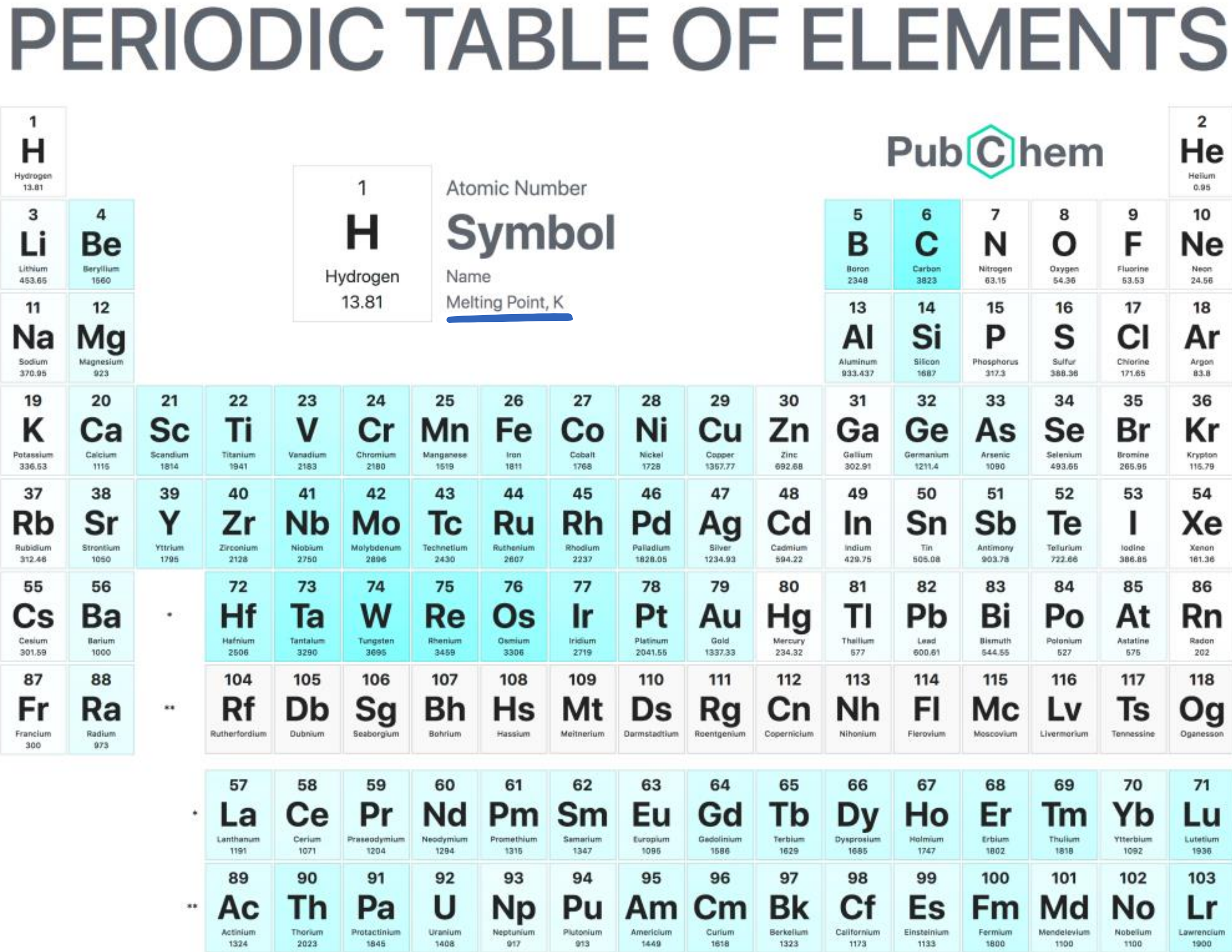
https://pubchem.ncbi.nlm.nih.gov/



Periodic table - melting point

September 6, 2024 8:18 AM

https://pubchem.ncbi.nlm.nih.gov/



Periodic table - 'standard state'

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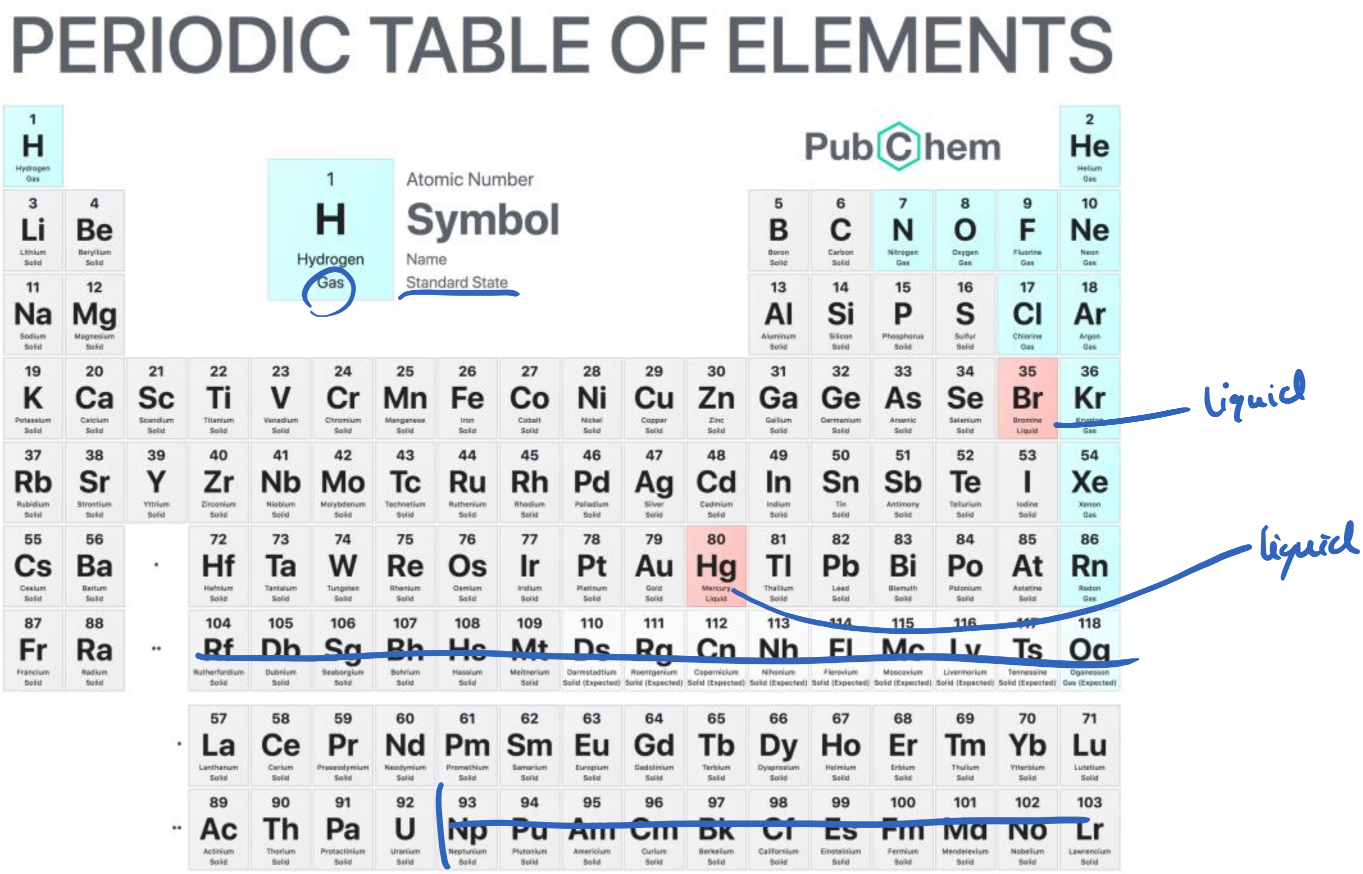


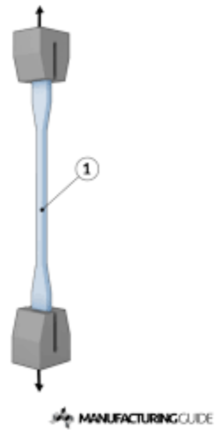
Hooke's Law

September 5, 2024 2:34 PM

$F = k\Delta x$

Tensile Test

September 5, 2024 2:59 PM



APS110H1f2024 - Sept 9 2024

September 8, 2024 10:12 AM

strain
stress
not modern

metals

Ceramics

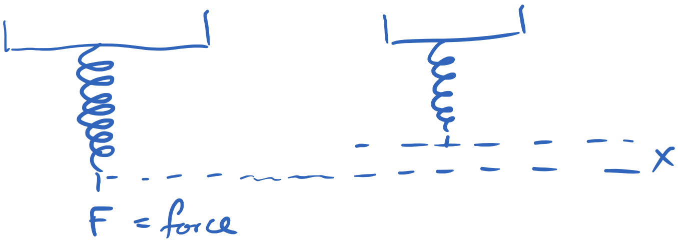
solids

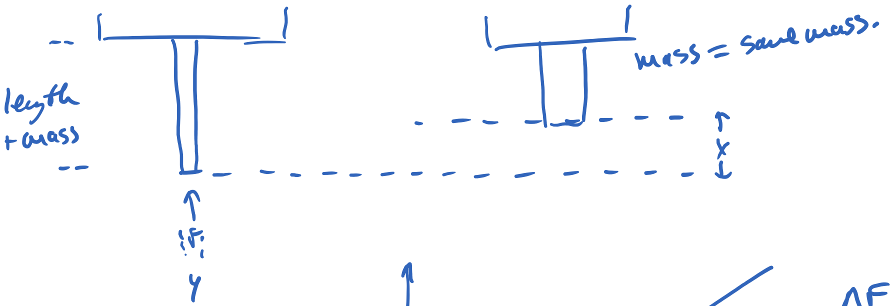
polymer/
plastics

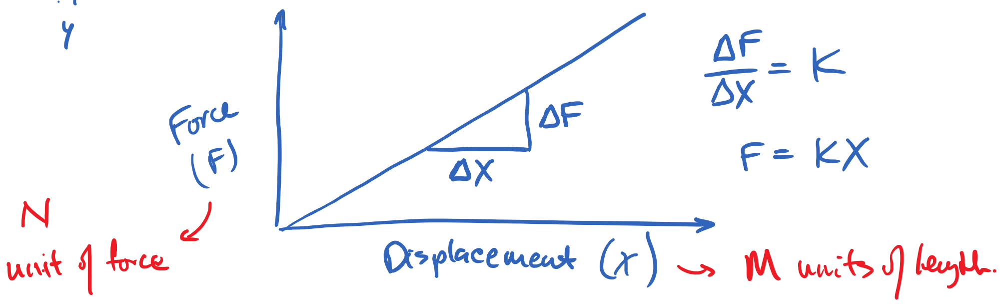
Mechanical
behavior

Hooke's Law

September 5, 2024 2:34 PM

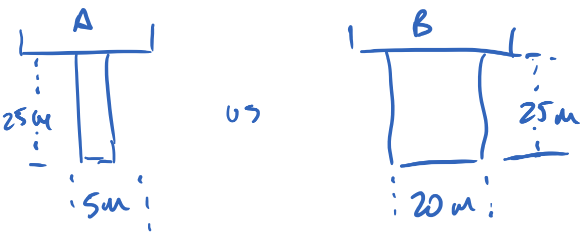


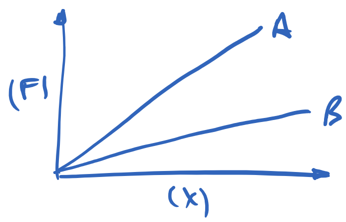




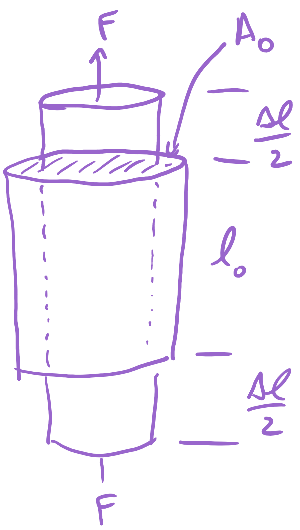
$$\frac{\Delta F}{\Delta X} = K$$

$$F = KX$$





stress / strain.

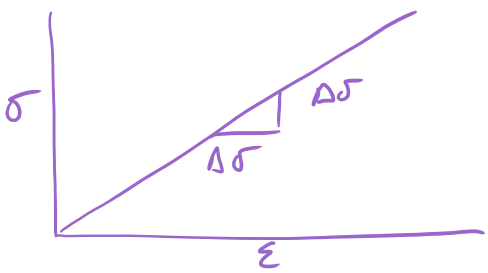


$\sigma = \frac{F}{A_o}$ — force / — initial area. = stress

"sigma"

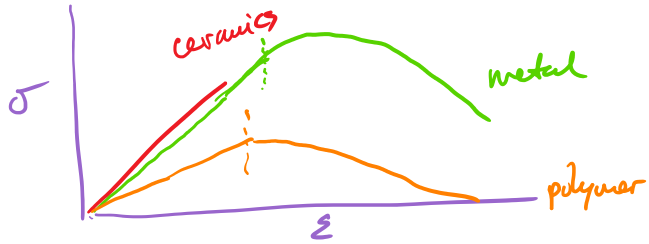
$\varepsilon = \frac{\Delta l}{l_o}$ = strain

"epsilon"



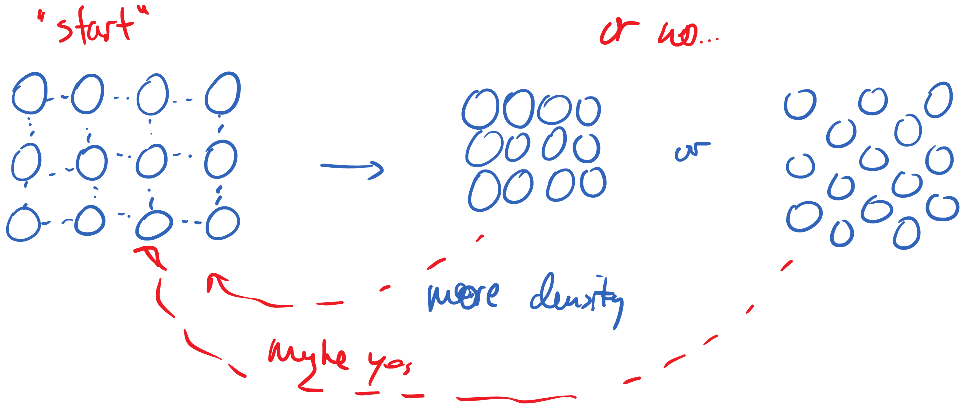
$$\frac{\Delta \sigma}{\Delta \varepsilon} = E$$

↑ "Young's"



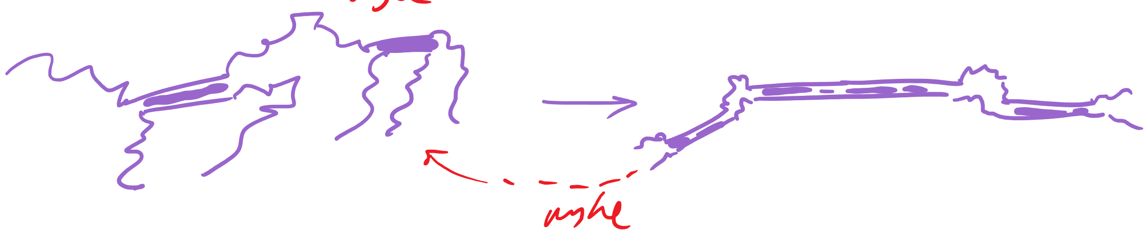
elastic

metal



example
CuO

polymer



… just an example

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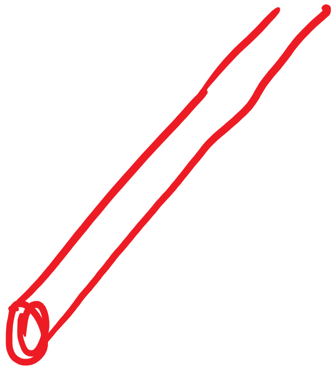

Tensile Test

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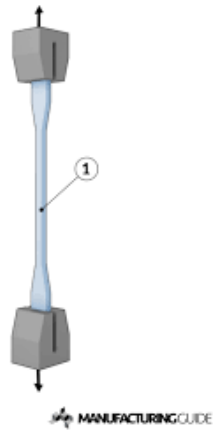
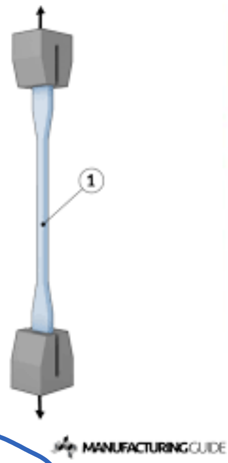
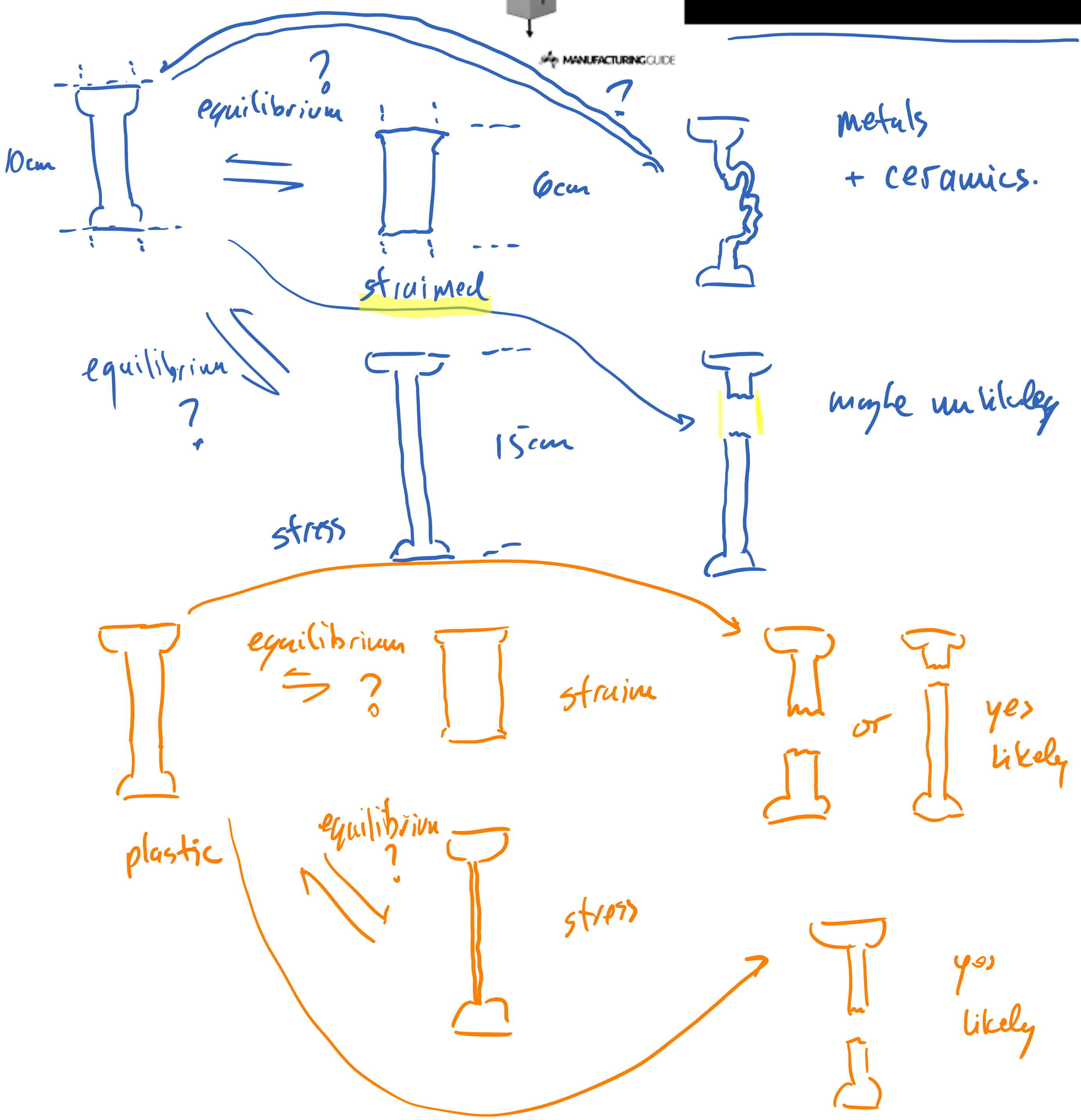


APS110H1f2024 - Sept 11 2024 - Tensile Test

September 5, 2024 2:59 PM





"Bending" method

September 11, 2024 3:40 PM

load/power

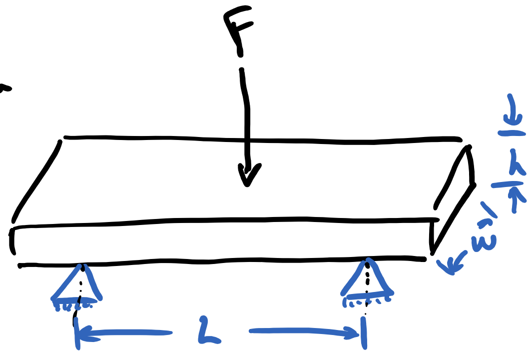
length

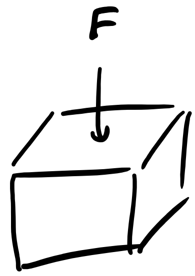
$$\sigma_{3\text{-pt}} = \frac{3FL}{2wh^2}$$

width

hieght

3-pt = 3 point bend strength





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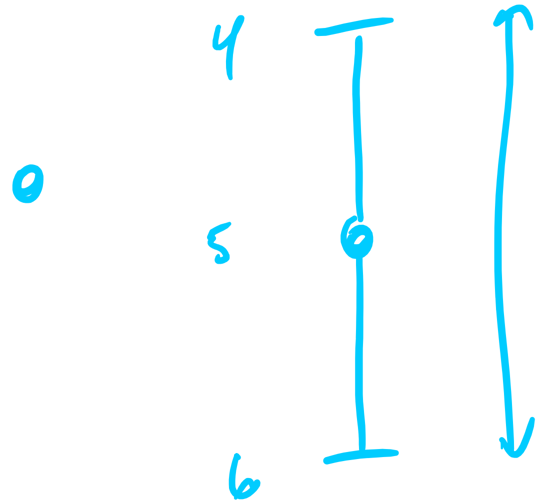


APS110H1f2024 - Sept 13 2024

September 12, 2024 2:44 PM

Density → Sept 16, 2024 / Monday

Demo

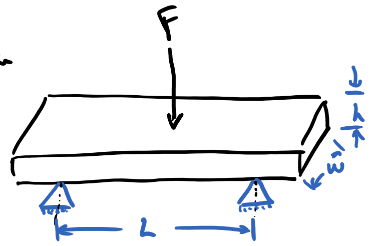
... was from 09-11-2024

September 11, 2024 3:40 PM

"Bending" method

$$\sigma_{3\text{-pt}} = \frac{3FL}{2wh^2}$$

load/power, length, width, hieght



$\sigma_{3\text{-pt}}$ = 3 point bend strength

$F = n\,Pa$ n = number

$$\sigma_{3\text{-pt}} = \frac{3\,Pa\ \ mm}{2\ \ mm\ \ mm^2}$$

$= n\ \ Pa/mm^2$ typo during glass :)

Demo

#1 glass

h - 4.8 mm = 0.48 cm

w - 152 mm = 15.2 cm

L - 250 mm = 25 cm data #1 ✗

382 mm = 38.2 cm data #2 ✗

116 mm = 11.6 cm data #3 ✓

#2

h - 2 mm = 0.2 cm

w - 152 mm = 15.2 cm

L - 116 mm = 11.6 cm data #3 ✓

382 mm = 38.2 cm data #2 ✗

250 mm = 25 cm data #1 ✗

---

metal

h - 4.0 mm = 0.40 cm

w - 154 mm = 15.4 cm

L 250 mm = 25.0 cm ~ 1st glass

382 mm = 38.2 cm - worse than 1st glass

116 mm = 11.6 cm - seems "ok"

---

plastic

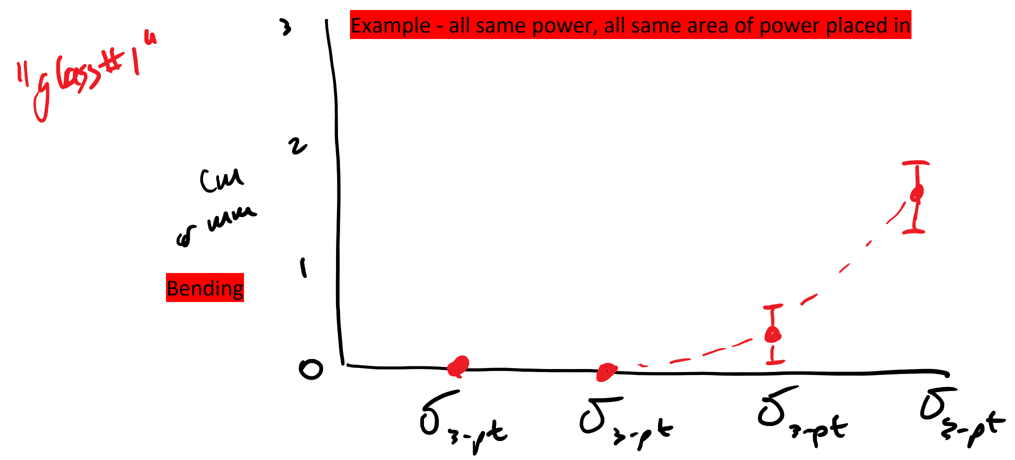
h - 6.0 mm = 0.6 cm

w - 156.0 mm = 15.6 cm

L 250 mm = 25.0 cm X

382 mm = 38.2 cm X

116 mm = 11.6 cm maybe

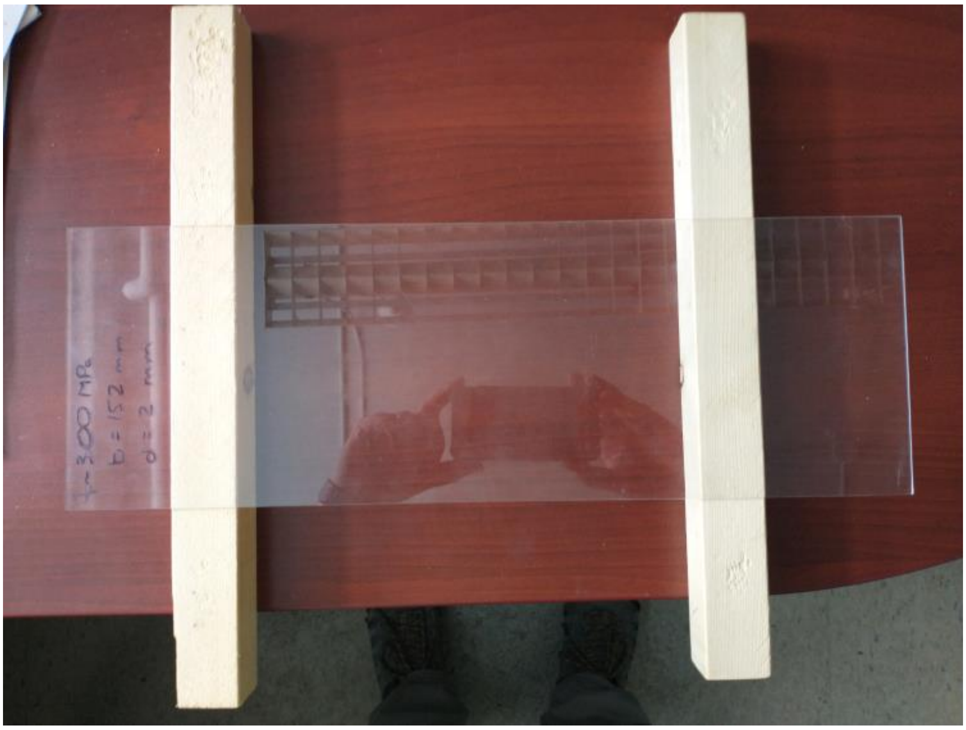


Glass 1

September 13, 2024 4:14 PM

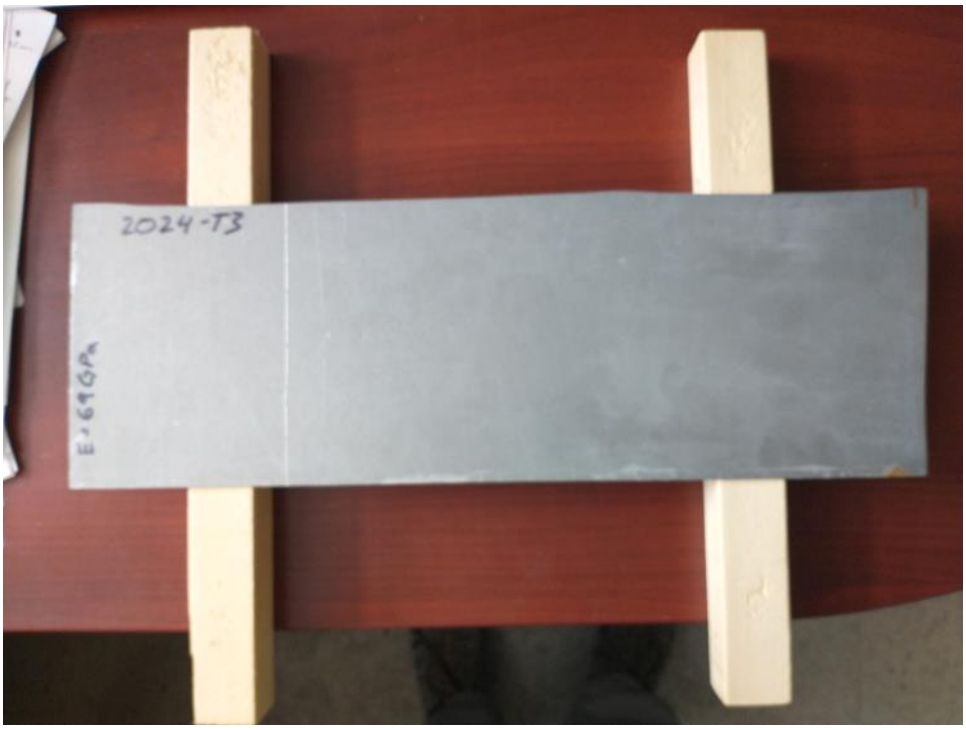
Glass 2

September 13, 2024 4:14 PM



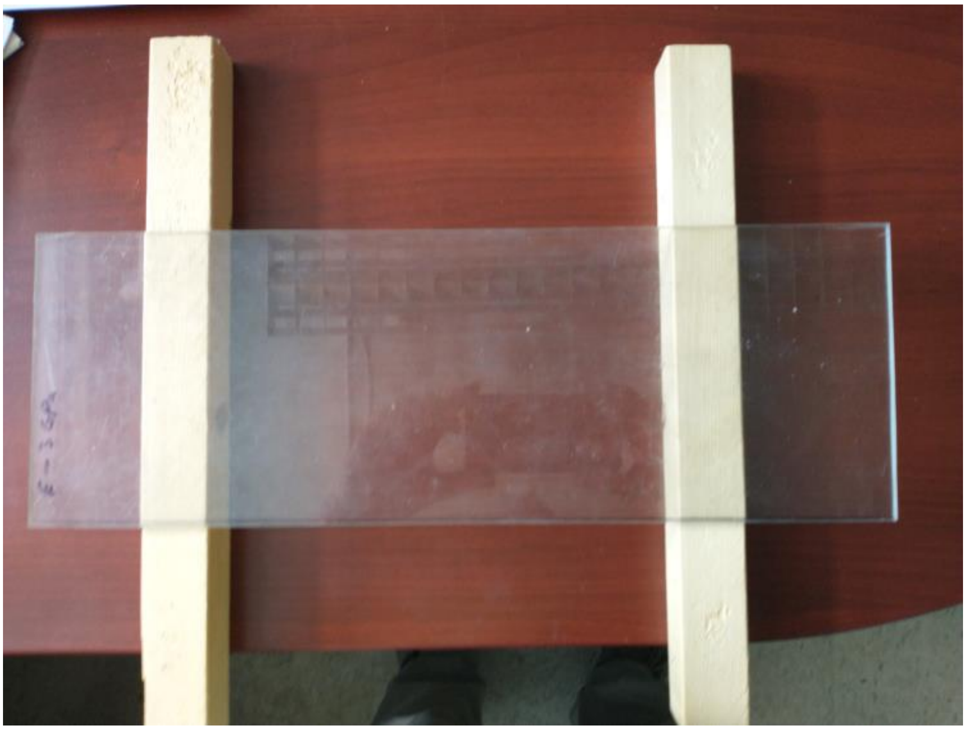
Metal

September 13, 2024 4:14 PM



Plastic

September 13, 2024 4:15 PM



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Density

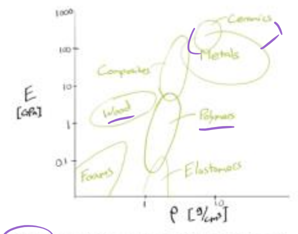
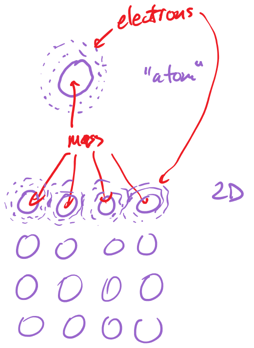
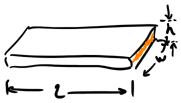


Figure 1: A plot of Young's modulus versus density on logarithmic axes.

Q:





h 4.0 mm = 0.4 cm

w 154 mm = 15.4 cm

L 406.2 mm = 40.62 cm

area $\Rightarrow A = h \times w$

mass $\Rightarrow m = A \times L \times \rho$

$= h \times w \times L \times \rho$

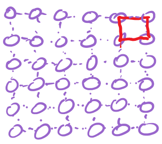
ρ = density

ρ

maybe can be engineered

unit cell

2D

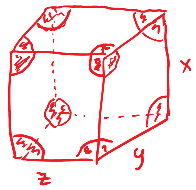


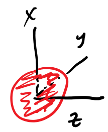
metal

3D unit cell

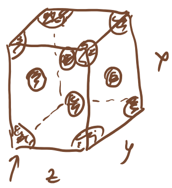
- data available

"square"



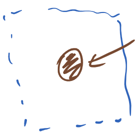


1/8 of mass within the unit.

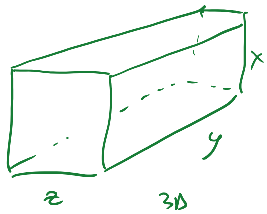


1/8.

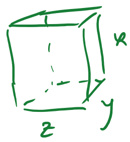
1/2 of mass



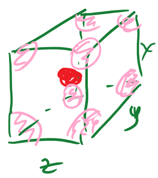
100% mass



3D unit cell



3D unit cell



1/8 % - CuO - 100%

also applies to the ceramics

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Density

metal

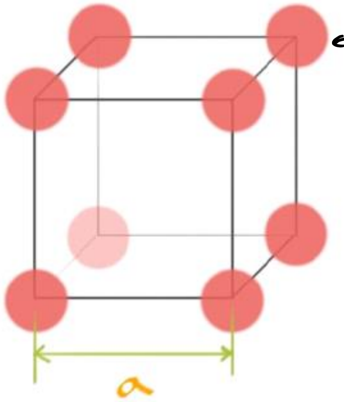
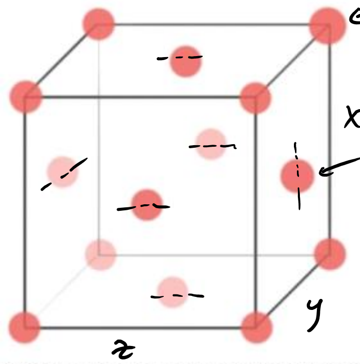


Figure 4: The simple cubic unit cell, showing an atom centred at each of the eight corners of a cube. The lighter red dots are the atoms located on the hidden parts of the cube. The cube edge length is known as the lattice parameter and is denoted with the letter a.

Metal



$1/8 \times 8 = 1$

$1/2 \times 6 = 3$

$\Rightarrow 4 \overset{=n}{}$ atoms in unitcell

unit cell

FCC = face central cubic

Figure 5: The FCC unit cell, showing an atom centred at each of the eight corners of a cube as well as one atom centred at the very centre of each of the six cube faces. The lighter red dots are the atoms located on the hidden parts of the cube.

$$\text{density} = \rho = \frac{\text{mass of atoms}}{\text{volume of unit cell}} = \frac{m}{V} \left(\frac{g}{cm^3} \text{ or } \frac{kg}{m^3} \right)$$

$$\boxed{\rho = \frac{n \cdot A}{V_c \cdot N_A}}$$

n: # of atoms in the unit

A: molar mass

N_A: Avagadro's number $= 6.023 \times 10^{23}$

V_c: volume of unit cell = x × y × z

nano

1 nano gram $= 1 \times 10^{-9}$ gram

1 gram $= 1 \times 10^{9}$ nano gram

Ceramics

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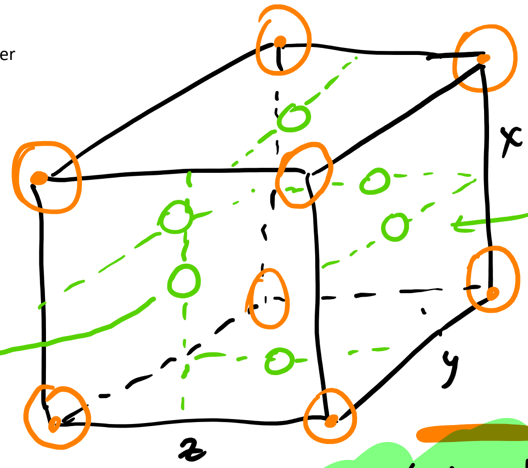
Metals + metalloids can be mixed together

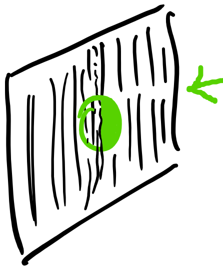
Pd + Se

palladium + selenium

Palladium is a metal

Selenium is a metalloid





$\frac{1}{8} \times 8 = 1$

Pd

$\frac{1}{2} \times 6 = 3$

Se

$$\rho = \frac{(n^1 \cdot A^1) + (n^2 \cdot A^2)}{V_c \cdot N_a}$$

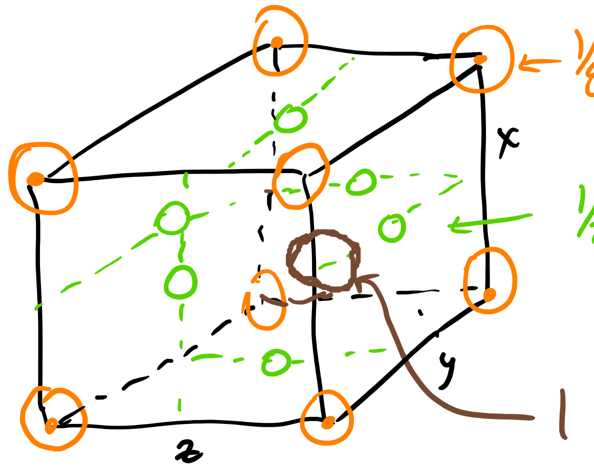
FYI - the atomic radius was not considered for this artwork and discussion - if data found you will atomic radiuses

Another example

another example

3 metals present.

3 metals present



$\frac{1}{8} \times 8 = 1$ Pd

$\frac{1}{2} \times 6 = 3$ Se

1

Fe

Fe/iron

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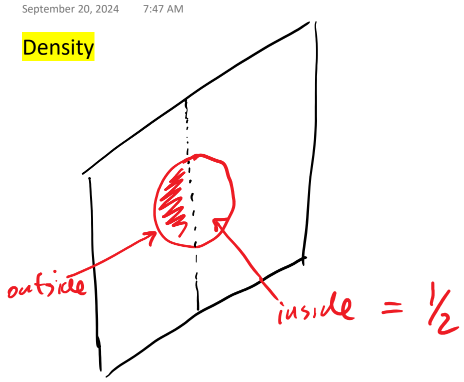
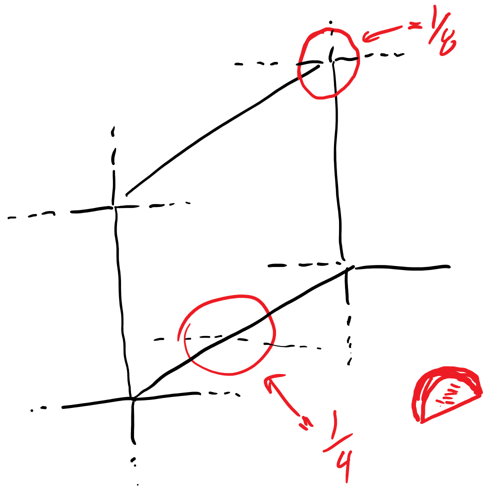
Density





$NaCl = NaCl \qquad Na^+ + Cl^-$

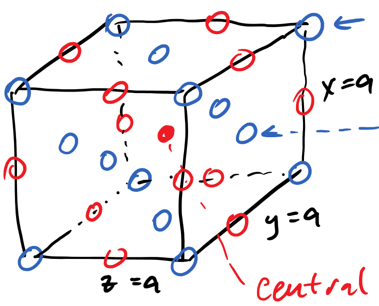
cation = C anion = A

$1^+ \qquad 1^-$

density $\rho = \dfrac{(n_A \cdot A_A) + (n_C \cdot A_C)}{V_C \cdot N_A}$

volume of unit cell Avagadro's number

$a^3 = x \cdot y \cdot z$



$\frac{1}{8} \times 8 = 1$

$\frac{1}{2} \times 6 = 3$

central = 1

$\frac{1}{4} \times 12 = 3$

Cl $3+1=4$

$4=4$

Na $3+1=4$

$Pd^{2+}Se^{2-}$ - another example.

$SiO_2 = Si^{4+} + 2O^{2-}$

Periodic Table

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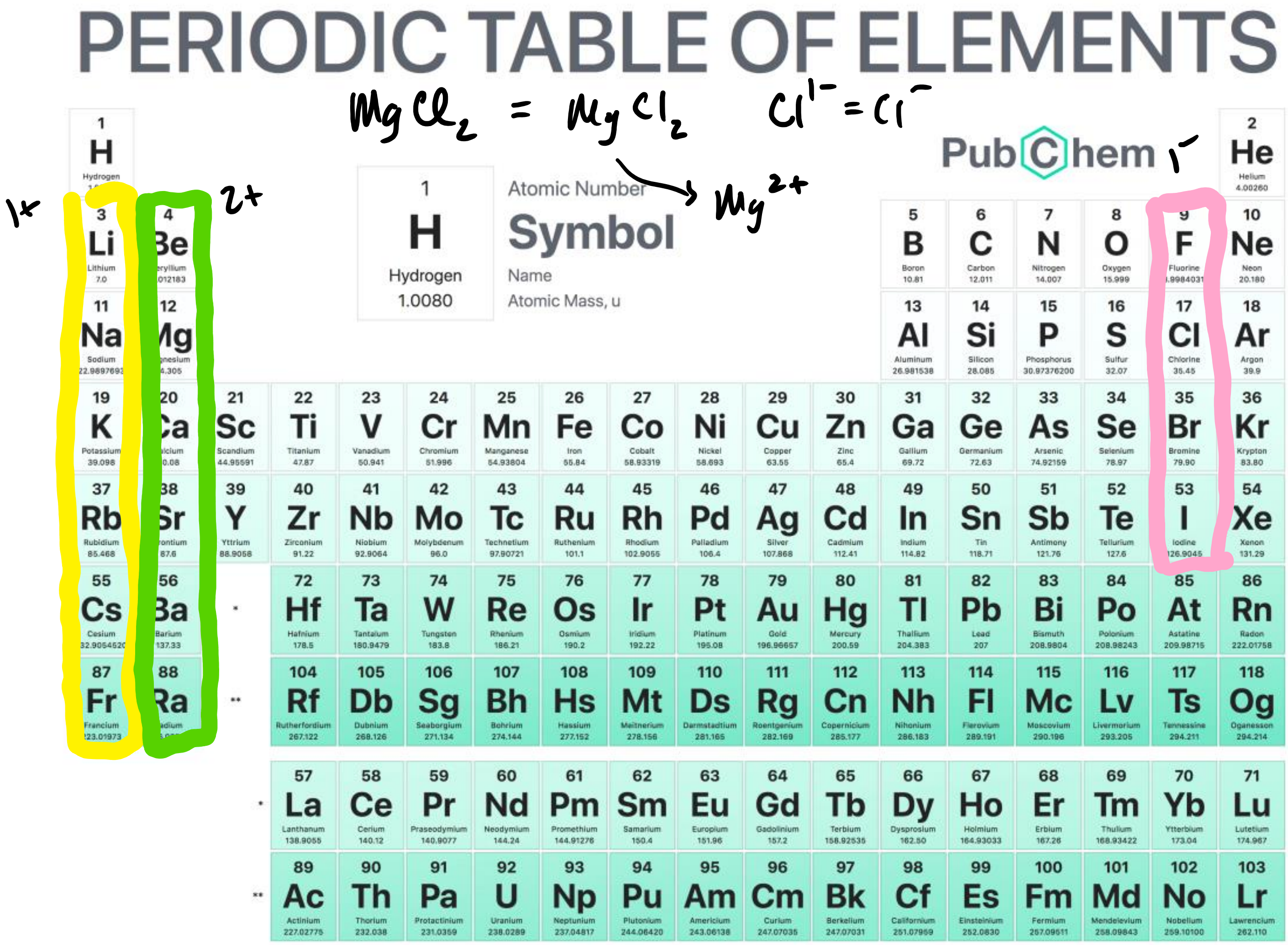

Face - centre Cubic

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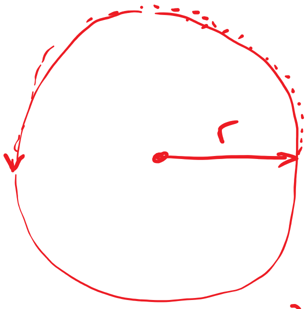
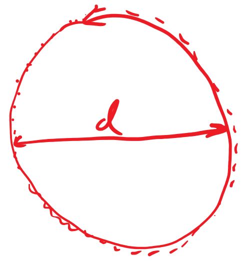
Atomic Packing Factor (APF)

2D



$r = 1$ $\pi = 3.14159 \times 2$

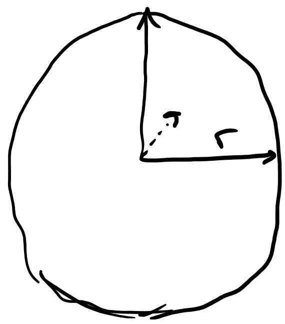


$d = 1$ $\pi = 3.1415926535$

$= 3.14159$

$$\text{volume} = \frac{4}{3}\pi R^3$$

of an atom / 1 atom.



3D

$1\ \text{pm} = 1e^{-10}\ \text{cm}$

$1\ \text{cm} = 1e^{10}\ \text{pm}$

FCC --> APF

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APF - atomic packing factor

$$APF = \frac{\text{volume}_{\text{spheres}}}{\text{volume}_{\text{unit cell}}}$$

atoms

$$APF = \frac{n \frac{4}{3} \pi R^3}{a^3}$$ only metals.

$$= \frac{n \frac{4}{3} \pi R^3}{x \cdot y \cdot z}$$ = only 1 metal

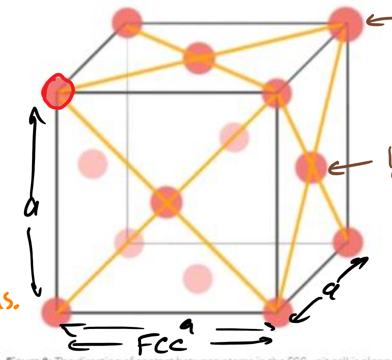
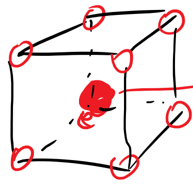


Figure 8: The direction of contact between atoms in the FCC unit cell is along the cube face diagonals, as illustrated by the orange lines.

$\frac{1}{8} \times 8 = 1$

$\frac{1}{2} \times 6 = 3$

$\rightarrow 4 = n$



$\frac{1}{8} \times 8 = 1$

$1 = 1$

$\rightarrow 2$

Fe / iron

↳ 194 pm

FCC - face centred cubic

$$a_{FCC} = 2\sqrt{2}R$$

$$= 548.7096 \text{ pm}$$

$\sqrt{2} = 1.4142$? Yes is a yes

$\sqrt{4} = 2$? Yes - is a yes

$$APF = \frac{n \, ^4/_3 \, \pi R^3}{FCC^3} = \frac{n \, ^4/_3 \, \pi R^3}{(2\sqrt{2}R)^3}$$

iron

$$APF = \frac{4 \cdot \frac{4}{3} \cdot 3.14159 \cdot (194 \text{ pm})^3}{(548.7096 \text{ pm})^3} = 668451.0380$$

density

Periodic Table

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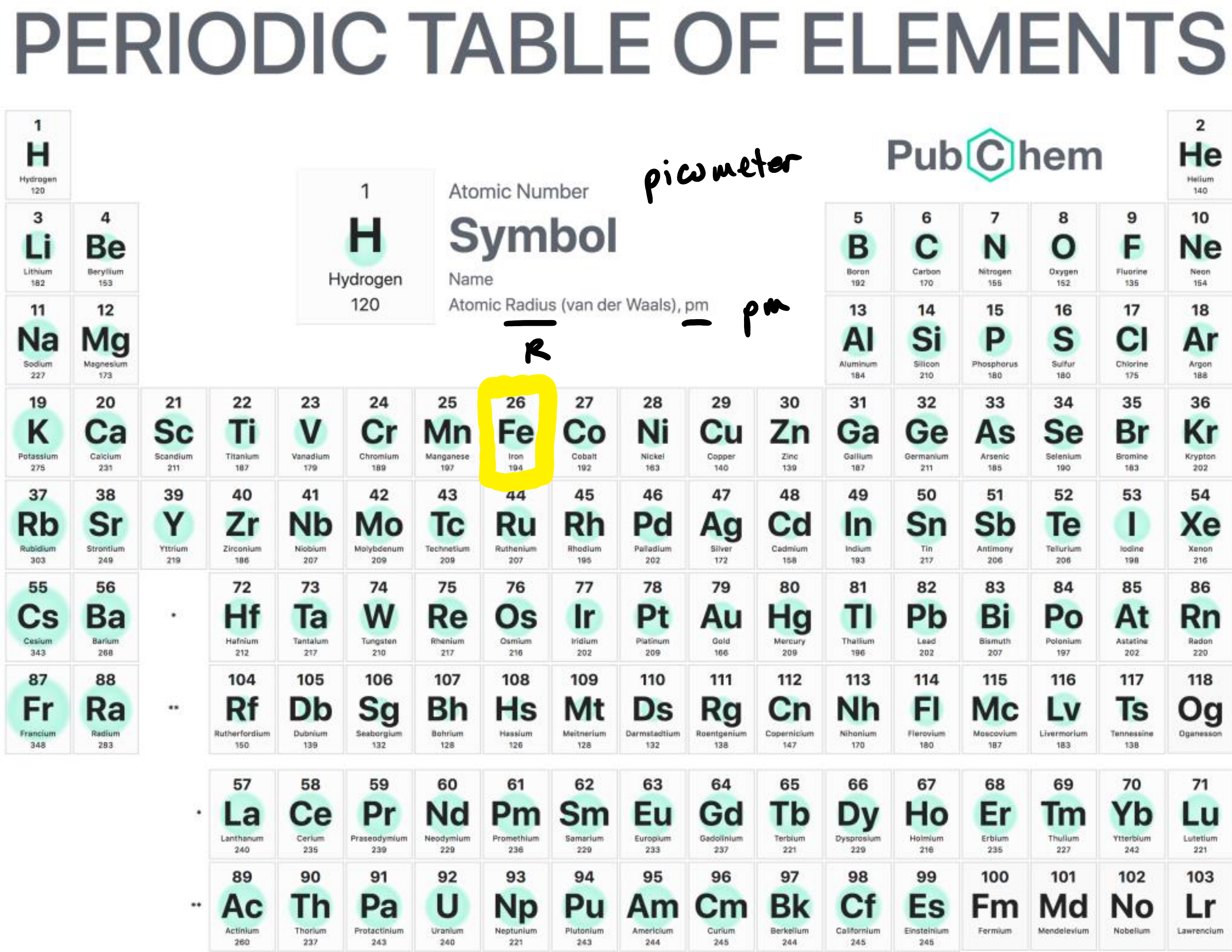

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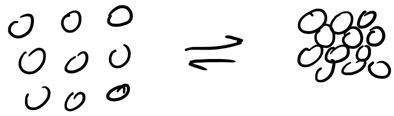
BCC --> FCC

BCC : Body Centred Cubic (Crystal Structure/Nanostructure)

stress + strain



metal only

$$CN_{BCC} = 8$$

coordination number

$$8 \times 1/8 = 1$$

$$n_{BCC} = 2$$

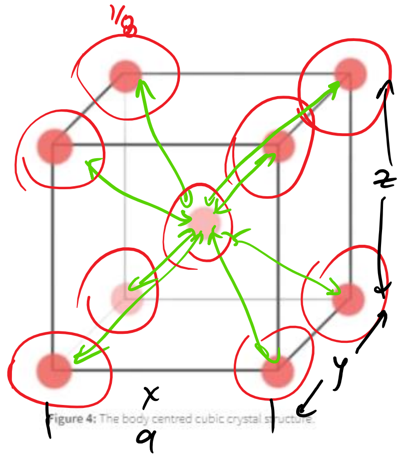
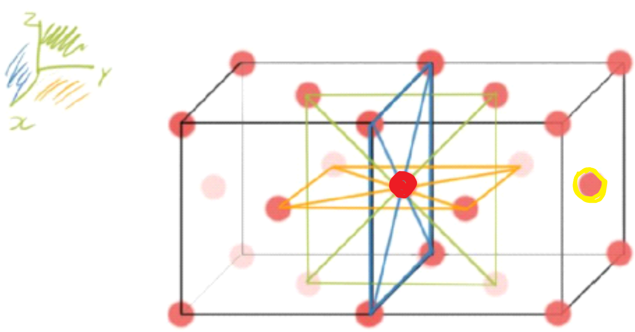


Figure 4: The body centred cubic crystal structure.

$$APF_{BCC} = \frac{n \frac{4}{3} \pi R^3}{a^3} = \frac{n \frac{4}{3} \pi R^3}{\left(\frac{4}{\sqrt{3}} R\right)^3} = 0.68$$

R = pm? nm? cm?

metals

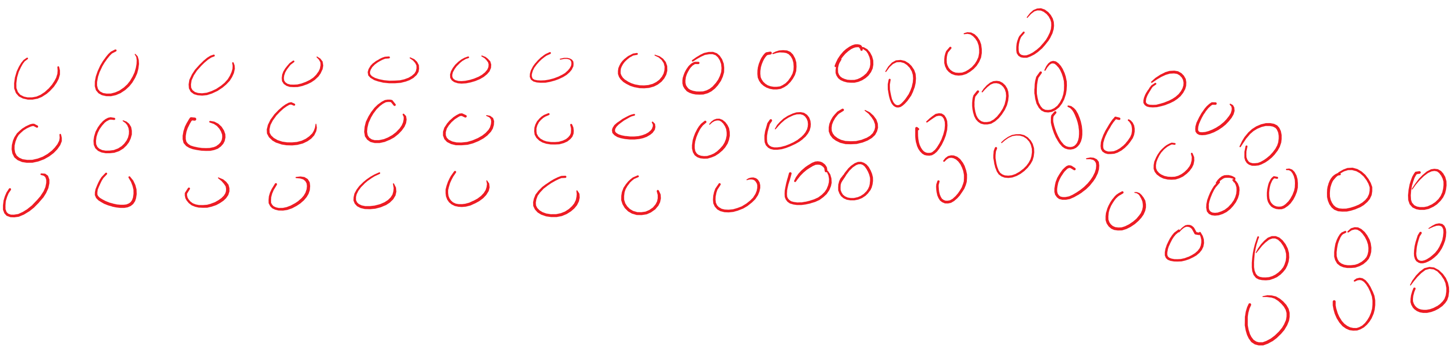


$$4 \times 1/4 = 1$$

$$8 \times 1/2 = 4$$

$$= 5$$

Figure 6: The coordination number for atoms in FCC. The right side face-centred atom makes contact with four atoms in the right side plane, with four atoms in the face-centred positions in the original unit cell, and with four atoms in teh face-centred positions in the unit cell to the right.



Octahedron

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$6 =$ coordinate number

$CN_{Bcc} = 6$

$12 \times 1/4 = 3$

$+1 = 4$

$8 \times 1/8 = 1$

$6 \times 1/2 = 3$

$= 4$

Cationic 1^+

anionic 1^-

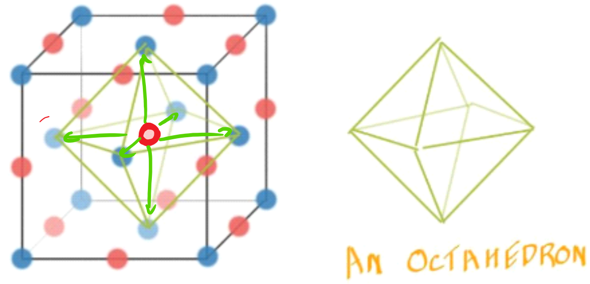

Figure 7: The octahedral interstitial site. Note that all cations, not just the central one, occupy octahedral interstitial sites within rock salt.

$4 = 4$

balance

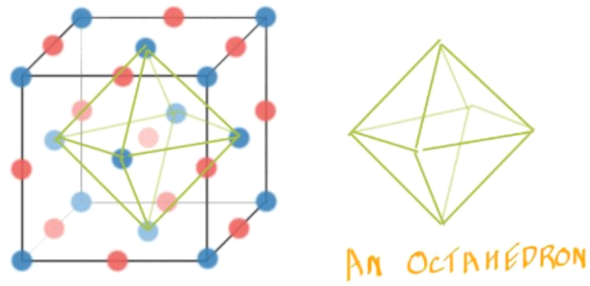

Figure 7: The octahedral interstitial site. Note that all cations, not just the central one, occupy octahedral interstitial sites within rock salt.

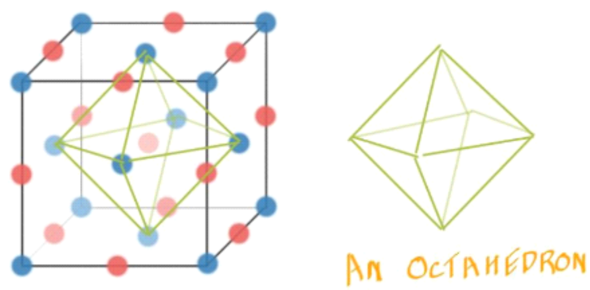

Figure 7: The octahedral interstitial site. Note that all cations, not just the central one, occupy octahedral interstitial sites within rock salt.

CaF_2

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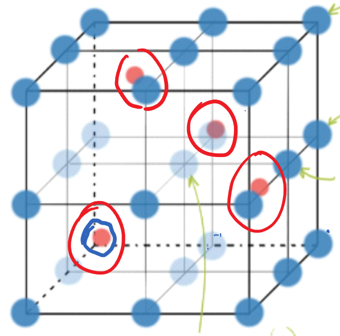
Ca^{2+}

F^{1-}



CORNERS $\left(\frac{1}{8}\right) \times 8 = 1$

EDGES $\left(\frac{1}{4}\right) \times 12 = 3$

FACES $\left(\frac{1}{2}\right) \times 6 = 3$

CENTRE $(1) = 1$

total $= 8. = F^{1-}$

$4 = Ca^{2+}$

CaF_2

Figure 8. There are 8 anions within the calcium fluorite ceramic crystal structure. The fraction of an atom for each position type is shown here.

$Ca = 231\ pm = 2.31 \times 10^{-8}\ cm = 0.231\ nm$

$F = 135\ pm = 1.35 \times 10^{-8}\ cm = 0.135\ nm$

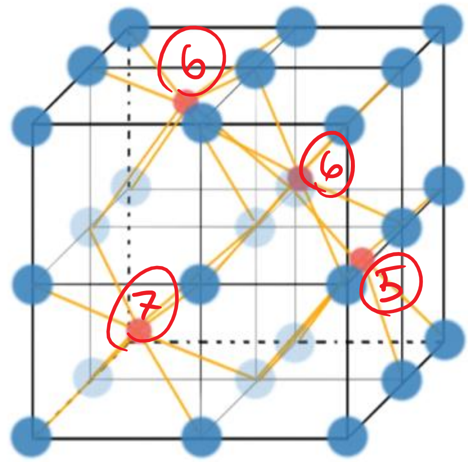


Figure 6. The calcium fluorite ceramic crystal structure. Anions represented as blue dots are in a simple cubic lattice with half of the simple cubic interstitial sites occupied by cations. Cations touch their 8 nearest neighbour anions along the cube diagonals, as illustrated by the orange lines.

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The Size of Interstitial Sites

$$\boxed{\sin 45^\circ = \frac{1}{\sqrt{2}} = \frac{1}{1.414}}$$

$$\sin 45 = \frac{2R_A}{2R_A + 2R_c}$$

$$\frac{R_c}{R_A} = \frac{1 - \sin 45}{\sin 45}$$

$$= \frac{1 - \frac{1}{1.414}}{\frac{1}{1.414}}$$

$$\frac{R_c}{R_A} = 0.414$$

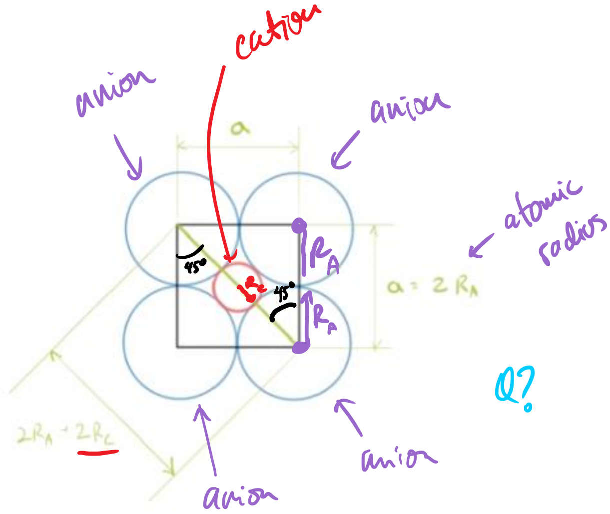
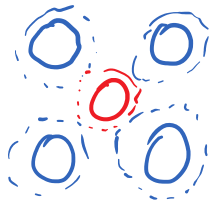


Figure 9: A 2D slice through the octahedral interstitial site at the geometrically ideal radius ratio when the anions are touching one another and the cation is just big enough to fit into the site without pushing the anions apart.



Hexagonal

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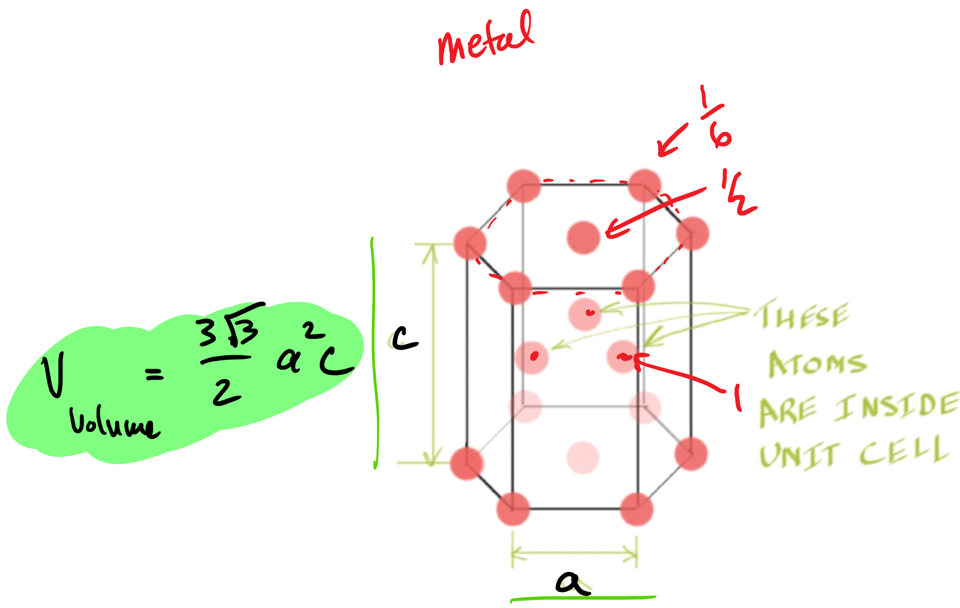

Figure 11: A hexagonal close packed unit cell. Note that the three atoms in the middle are inside the unit cell and are part of a close packed plane that is identical to the top and bottom planes.

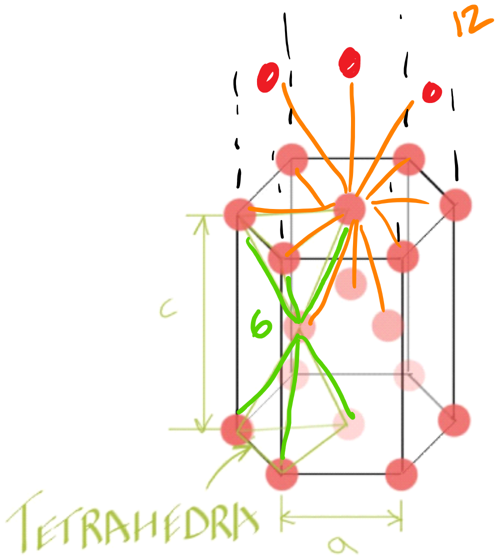

Figure 12: A hexagonal close packed unit cell showing the positioning of the three middle atoms nestled into the low spots between three atoms on the bottom plane.

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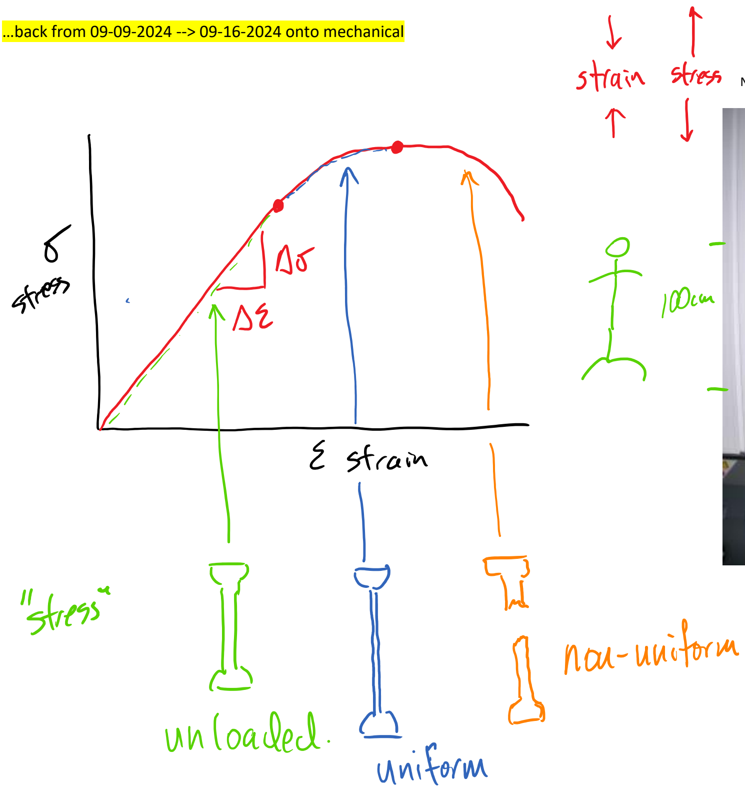
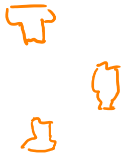
...back from 09-09-2024 --> 09-16-2024 onto mechanical

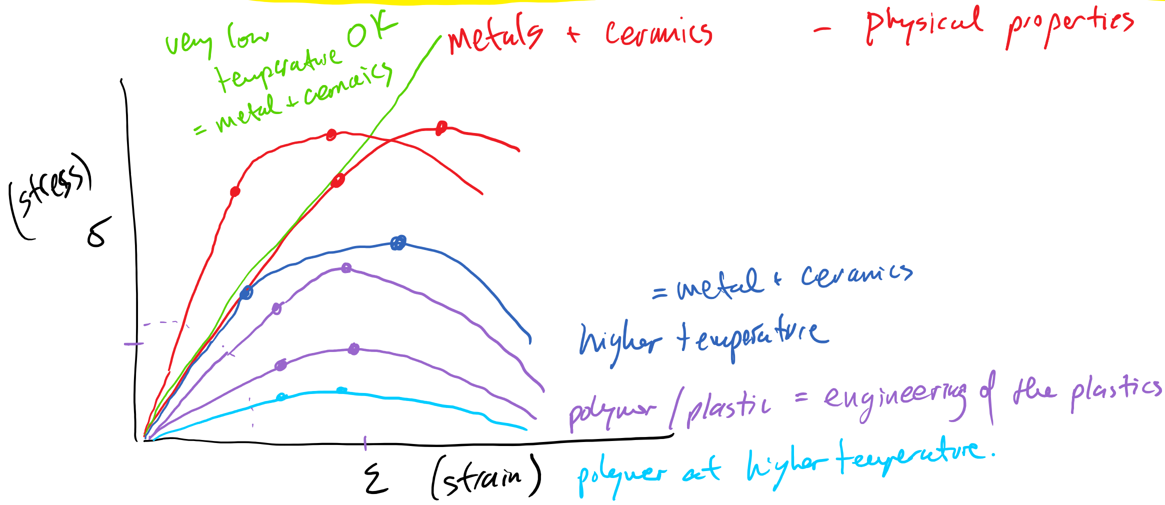


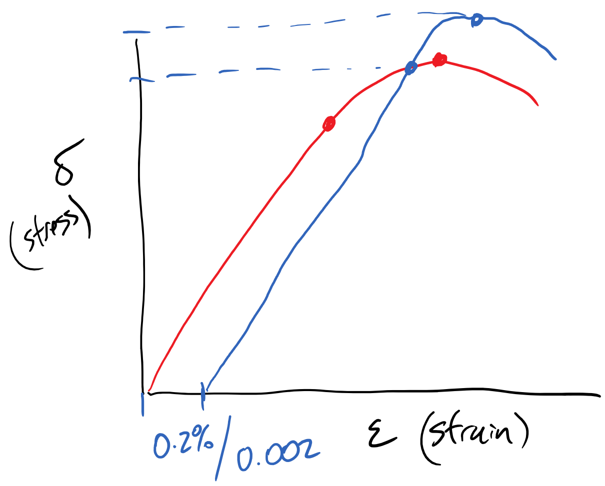
Nice picture from Wikipedia: Ultimate Tensile Strength

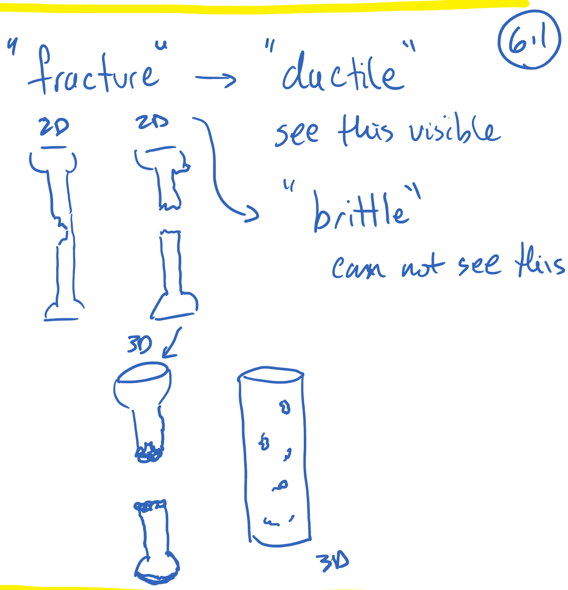


$\frac{\Delta \sigma}{\Delta \varepsilon} = E$

"Young's equation"

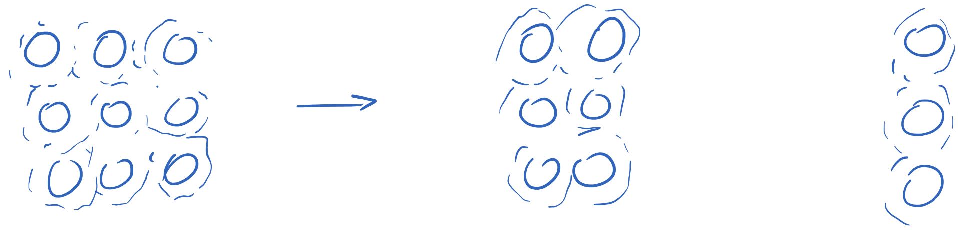




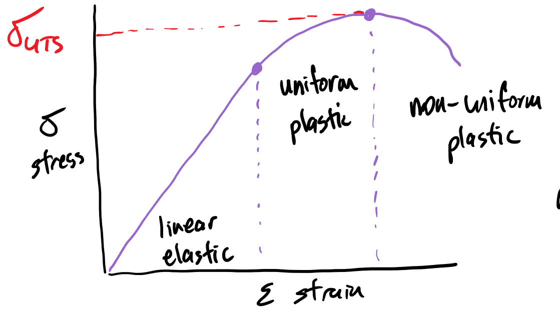


nano

nano
structure



UTS- Ultimate Tensile Strength



plastic is not "polymer/plastic"

2D

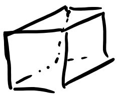
pure - all nano structure is consistent

vs non-pure (another example)

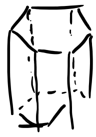
non-pure

or

nano unit cells 3D

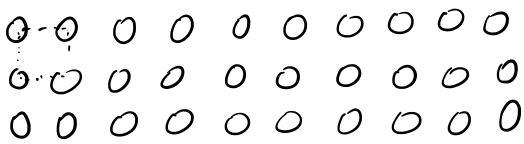


square / FCC octahedran

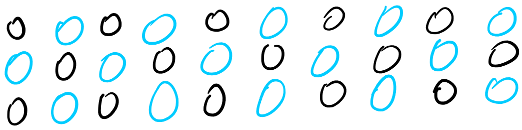


HCP / hexagonal

① pure 2D

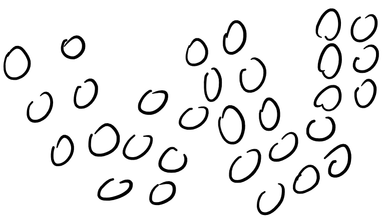


100% of metal



100% ceramic

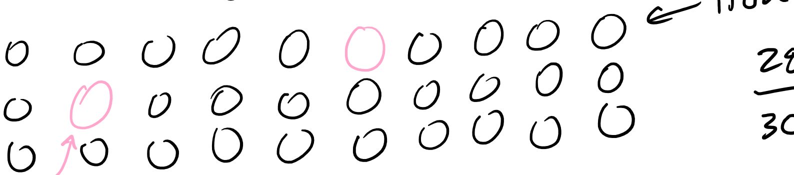
② non-pure



100% metal

also applies to the ceramics

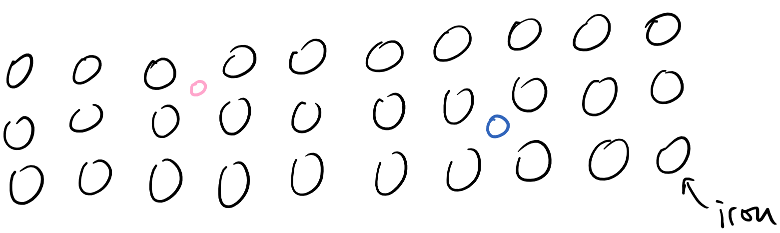
③ non-pure



$$\frac{28}{30} = 93.3\% \text{ pure}$$

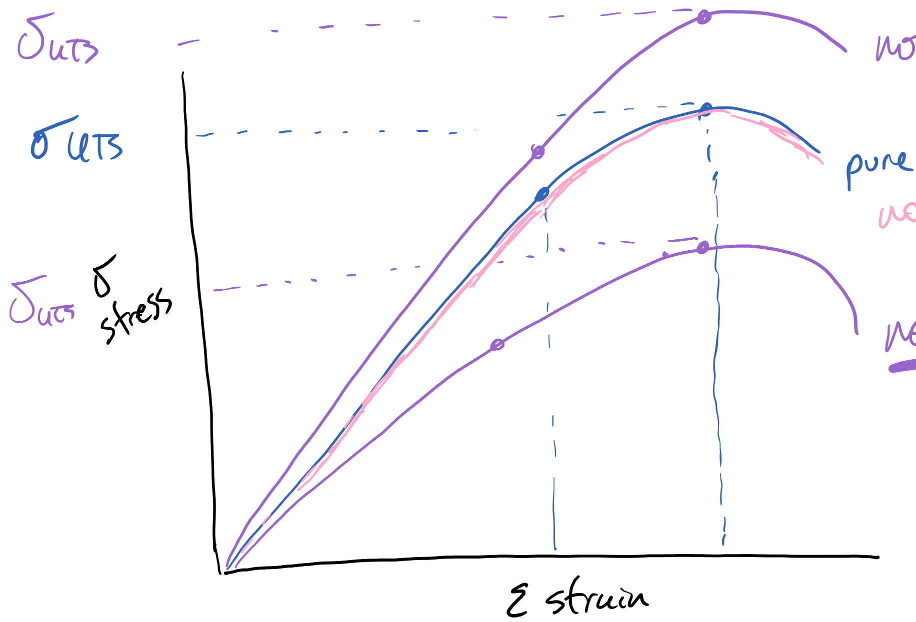
2 - present.

non-pure



NaF

- positive



non-pure – 60% ~ other %
– or non-nano structure

– maybe non-nano structure
non-pure – maybe the salt
– or 99% ~ other%

non-pure – negative
re impurity
93.3% ~ other%
– non-nano structure

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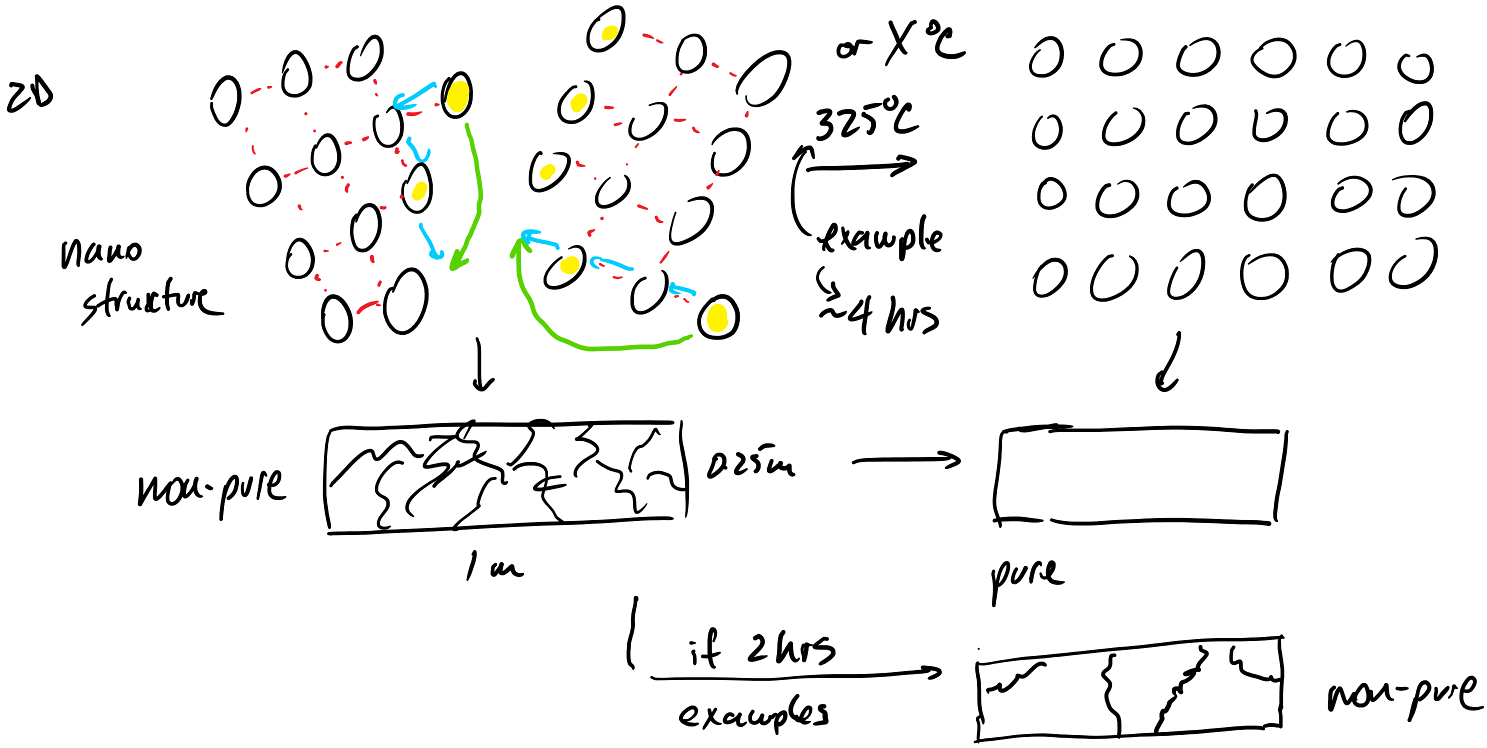
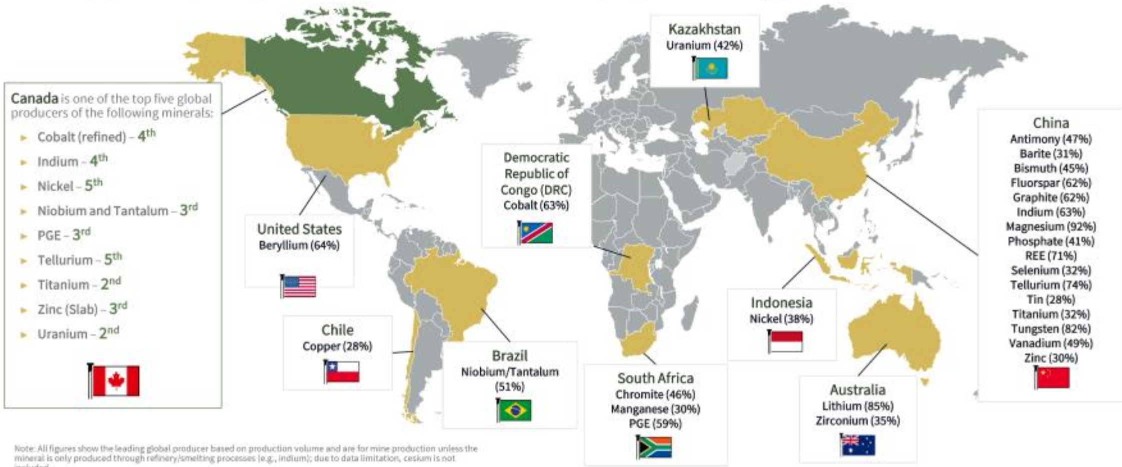
Thermodynamics and Kinetics



2.3 Leading Critical Minerals Producers

- To understand the global market and supply chain for critical minerals, global mineral production data was assessed in order to identify the top producer for each mineral and their respective market shares. Based on 2019 production volumes, China dominates the global critical minerals mining market with the highest production share in 16 minerals included on Ontario's critical minerals list.
- Ontario's endowment with critical mineral deposits represents an opportunity for the province to produce and market responsibly procured natural resources to some of the major jurisdictions, including the US and the EU, whose advanced industries rely on global minerals' supply chains.



Note: All figures show the leading global producer based on production volume and are for mine production unless the mineral is only produced through refinery/smelting processes (e.g., indium); due to data limitation, cesium is not included.
Source: British Geological Survey (BSG).

2.4 Substitutability and Importance in Major Jurisdictions

- Some industrial applications can use multiple source materials, while others require very particular and limited inputs. In order to assess the substitutability of each critical mineral, this report analyzes each mineral's applications and availability of alternative materials with comparable properties and performance for the most common industrial needs.
- Assessing substitutability with the mineral's criticality status in major jurisdictions (as defined by national critical minerals frameworks in each country included in the analysis) provides a view of the overall economic and strategic importance of these minerals on a global scale.

Table 7: Ontario's Critical Minerals: Substitutability and Importance in Major Jurisdictions

Mineral	Status in Ontario	Substitutability (Low-High)	Minerals Included on Critical Minerals List						
			EU	US	UK	Canada	Japan	Australia	Total Jurisdictions
Antimony	Exploration Project	Moderate	√	√	√	√	√	√	6/6
Barite	Advanced Mineral Projects	Moderate	√	√					2/6
Beryllium	Exploration Potential	Low	√	√	√			√	4/6
Bismuth	Exploration Potential	High	√	√		√		√	4/6
Cesium	Exploration Potential	Moderate		√		√			2/6
Chromite	Advanced Mineral Projects	Low		√		√	√	√	4/6
Copper	Produced and Processed	Low				√		√	2/6
Cobalt	Produced and Processed	Moderate	√	√	√	√	√	√	6/6
Fluorspar	Exploration Potential	High	√	√	√	√			4/6
Graphite	Advanced Mineral Projects	Moderate	√	√	√		√	√	5/6
Indium	Produced	Low	√	√	√	√	√	√	6/6
Lithium	Advanced Mineral Projects	Moderate	√	√		√	√	√	5/6

Note: Status in Ontario indicated the most advanced stage for a given mineral. Most minerals that are produced as of 2021 also have advanced mineral projects and exploration potential. Complete critical minerals lists of comparable jurisdictions are provided in Appendix B.
Sources: United States Geological Survey (USGS); Critical Minerals lists of the EU, the US, the United Kingdom (UK), Japan, Canada, and Australia (**Critical mineral lists of major jurisdictions**).

2.4 Substitutability and Importance in Major Jurisdictions (continued)

Mineral	Status in Ontario	Substitutability (Low-High)	Minerals Included on Critical Minerals List						
			EU	US	UK	Canada	Japan	Australia	Total Jurisdictions
Magnesium	Advanced Mineral Projects	High	√	√	√	√	√		5/6
Manganese	Exploration Potential	Low		√		√	√	√	4/6
Molybdenum	Exploration Potential	Low				√		√	2/6
Nickel*	Produced and Processed	High		√		√		√	3/6
Niobium/Tantalum	Advanced Mineral Projects/ Exploration Potential	Moderate	√/√	√/√	√/√	√/√	√/√	√/√	6/6
Phosphate	Exploration Potential	Low	√						1/6
PGE	Produced and Processed	Moderate	√	√	√	√	√	√	6/6
REE	Exploration Potential	Moderate	√	√	√	√	√	√	6/6
Selenium	Produced and Processed	Moderate						√	1/6
Tellurium	Produced and Processed	Moderate		√		√			2/6
Tin	Exploration Potential	High		√		√		√	3/6
Titanium	Exploration Potential	Moderate	√	√		√	√	√	5/6
Tungsten	Exploration Potential	Low	√	√	√	√	√	√	6/6
Uranium	Processed Only	Moderate		√		√			2/6
Vanadium	Exploration Potential	Moderate	√	√		√	√		4/6
Zinc*	Produced	High		√		√			2/6
Zirconium	Exploration Potential	Moderate		√			√	√	3/6

Notes: *Nickel and Zinc were added to the US Critical Minerals List based on the 2021 US Administration review. Complete critical minerals lists of comparable jurisdictions are provided in **Appendix B**.
Sources: USGS; Critical Minerals lists of the EU, the US, UK, Japan, Canada, and Australia (**Critical mineral lists of major jurisdictions**).

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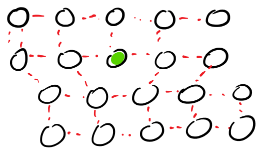
October 7, 2024 12:16 PM

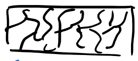
Thermodynamics and Kinetics

Crystalline Imperfections → nano-engineering of the structures

- Zero - dimensional - vacancy, impurity
- One - dislocation
- Two - grain, boundary



← less density



"non-pure"

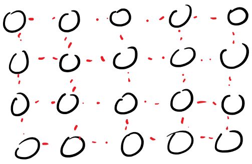
density change

← more density

"one"

"one"

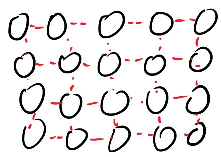
100°C or 400°C



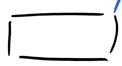
"less density"

"pure"

400°C or 100°C

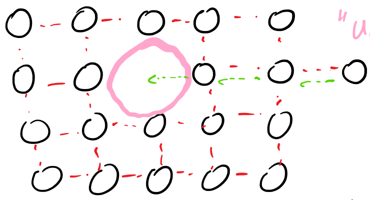


"more density"



"pure"

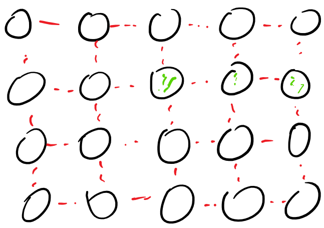
"zero"



"un-pure" "non-pure"

330°C "just an example"

"vacancy" "pure"



$$\frac{N_v}{N} = \exp\left(\frac{-Q_v}{KT}\right)$$

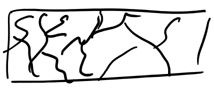
N_v: # of vacancy

N: total

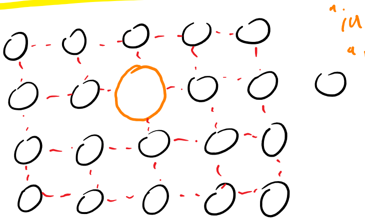
Q_v: energy

T: temperature

K: Boltzmann number

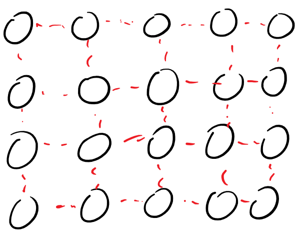


"zero"



"in-purity" "un-pure" "non-pure"

450°C "just an example"

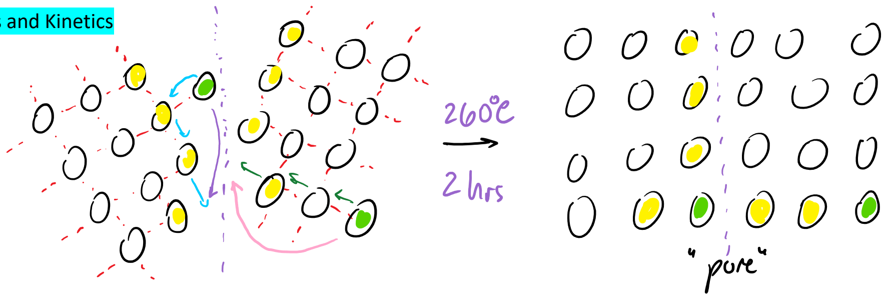


\+ waste / separation

pure - 100%

Thermodynamics and Kinetics

"non-pure"

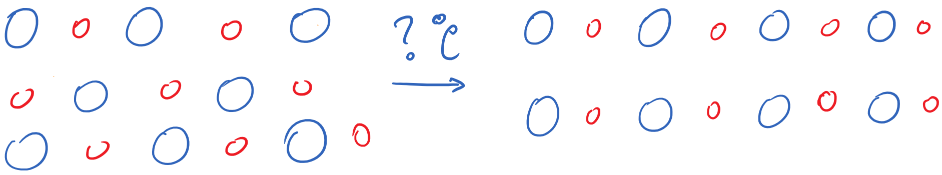


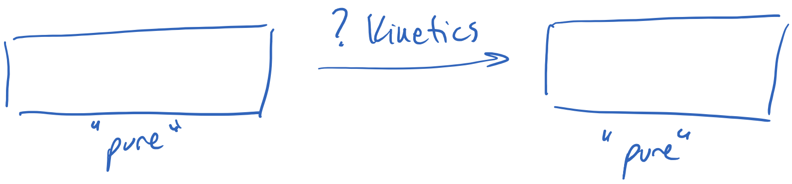
1+1 = 2hrs

$Cs^+ Cl^-$ $\quad$ $Cl = Cl$

175 pm

343 pm

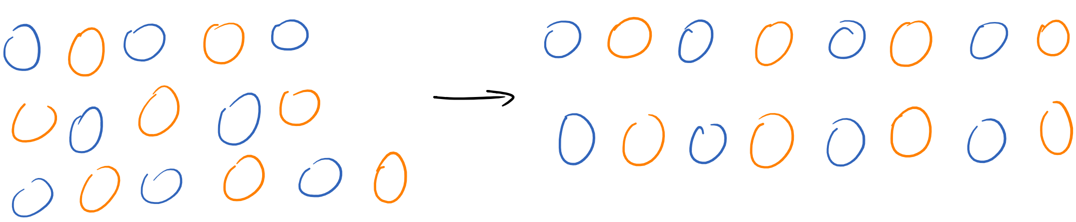




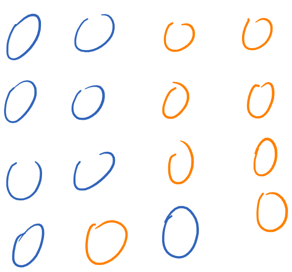
50:50

$\frac{1}{2} : \frac{1}{2}$

1 : 1



250°C

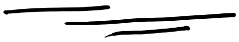


"non-pure"

Polymer introduction

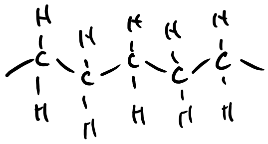
October 8, 2024 4:39 PM

Polymer

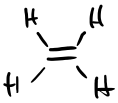


"stronger mech"

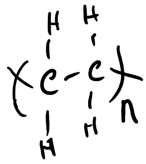
poly ethylene



ethylene → =



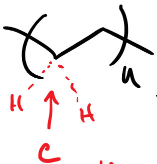
"high school"

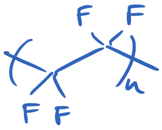


"university/industrial"

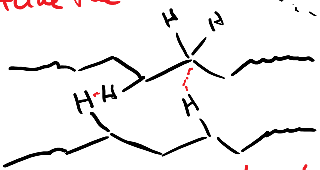
outline the atoms

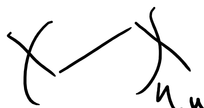
"another example"





"nano structure"





"industrial"

"language"

\# of carbons

1- methyl

2 - ethyl =

3- propyl

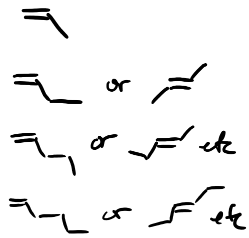
4- butyl

5- pentyl

6- hexyl

7- heptyl

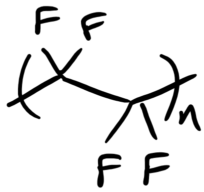
8- octyl



FYI = Monday Oct 21, 2024. mid-term

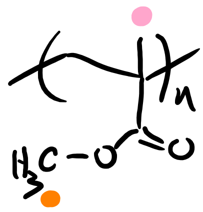
Introducing Polymers

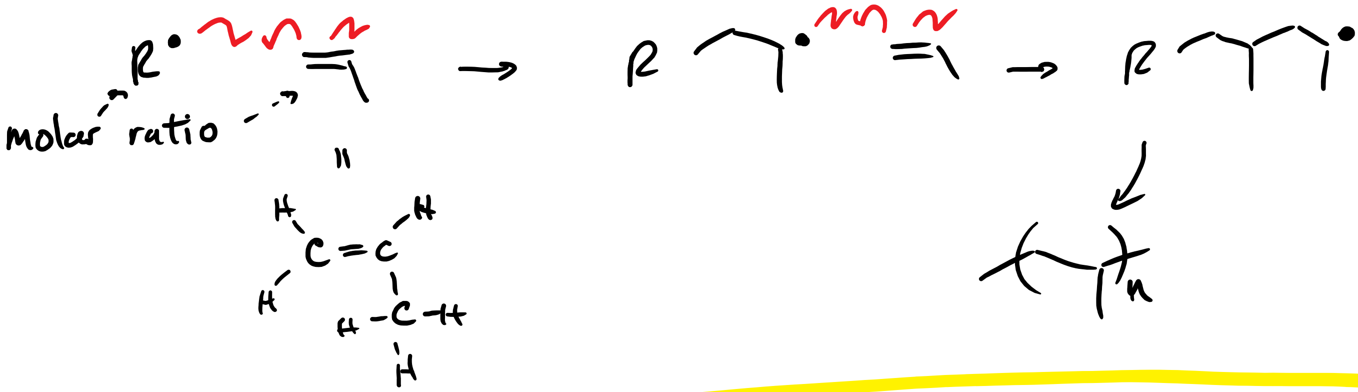
#4 poly tetra fluoro ethylene
= Teflon

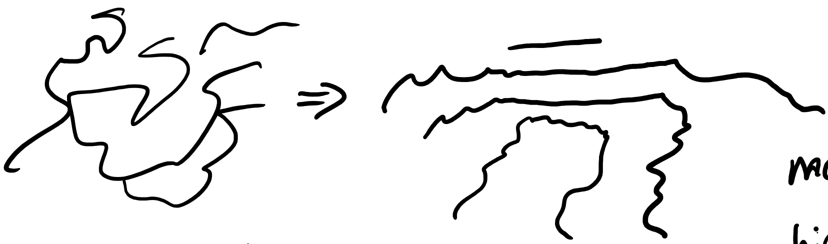


always linear

#5 poly methyl meth acrylate

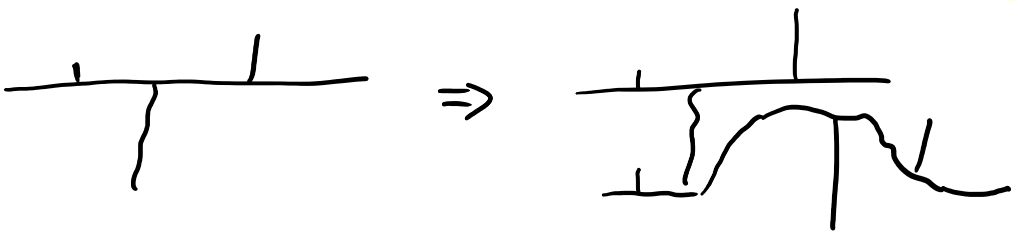






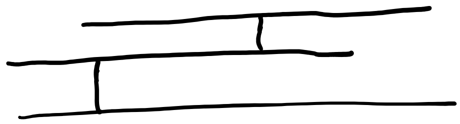
more -density
higher -density

more -density
higher density



lower -density

cross-coupling

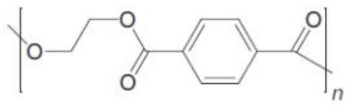
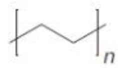
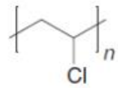
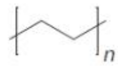
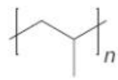
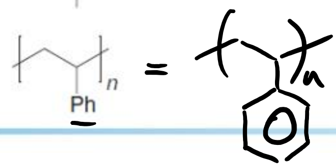


"higher density"

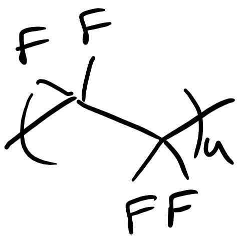
Recyclable Polymers

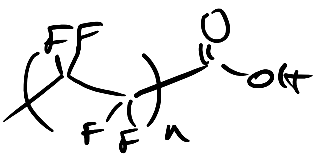
October 10, 2024 10:53 AM

Table 30.1 Recyclable Polymers

Recycling code	Polymer name	Structure	Recycled product
1	PET Polyethylene terephthalate		fleece jackets carpeting plastic bottles
2	HDPE High-density polyethylene #1		Tyvek insulation sports clothing
3	PVC Poly(vinyl chloride) #3		floor mats
4	LDPE Low-density polyethylene #1		trash bags
5	PP Polypropylene #2		furniture
6	PS Polystyrene #6		molded trays trash cans

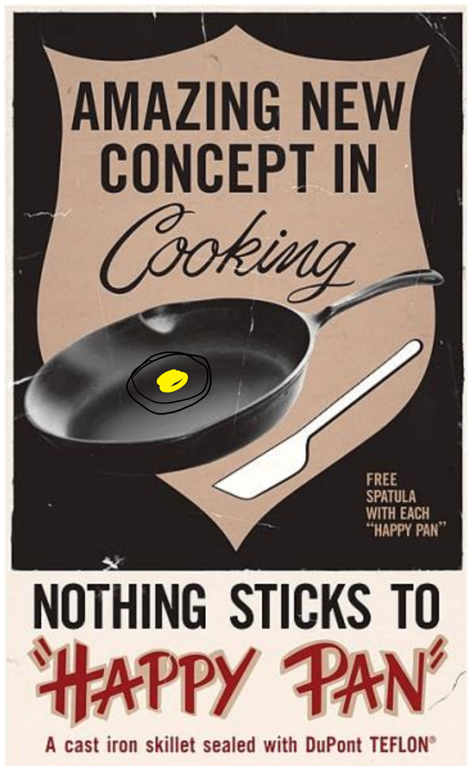
Non-recycling - founded in 1930-1960s





environmental "impact"

to waste in the environment



eggs

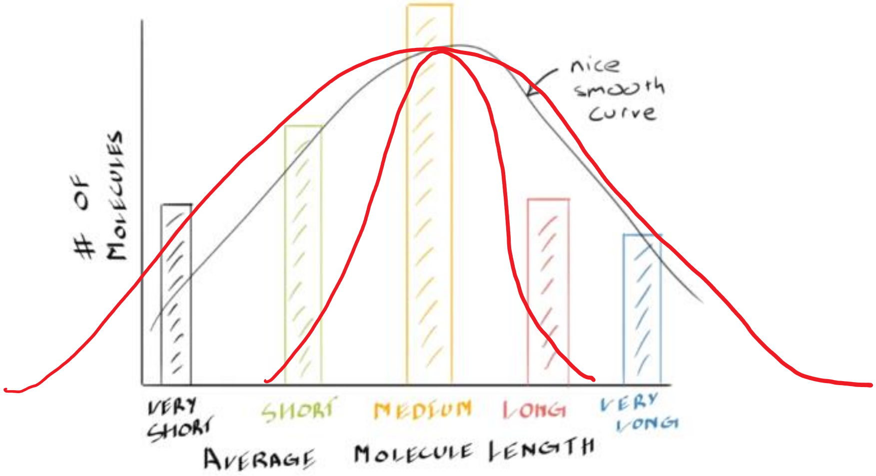


Figure 13. The molecular weight distribution for the hypothetical polymer sample in Figure 12. Our grouping into only five length groupings is very coarse and the actual distribution would be smooth, as shown by the nice smooth curve.

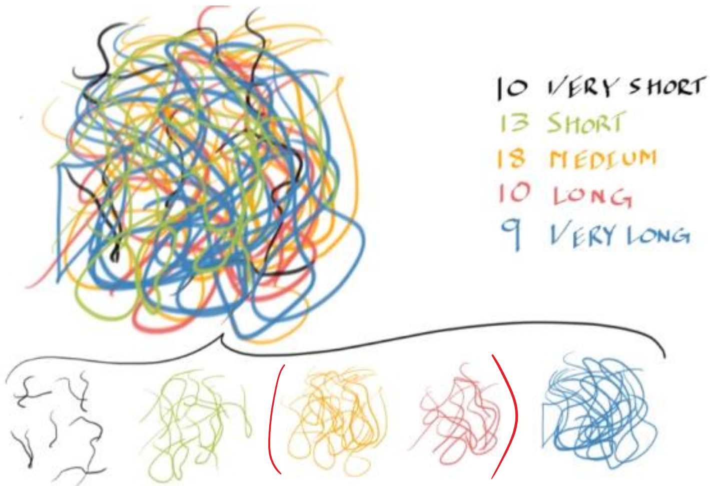
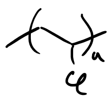


Figure 12. A hypothetical polymer sample consisting of some "very short" molecules, some "short" molecules, some "medium" molecules, some "long" molecules, and some "very long" molecules.

APS110H1f2024 October 16 2024

October 15, 2024 1:06 PM

Polymers



poly (vinyl chloride)

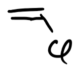
C_2 $12.01 \times 2 = 24.02$ mw

H_3 $1.00 \times 3 = 3.00$ mw

Cl_1 $35.45 \times 1 = 35.45$ mw

62.47 mw

precurser



"calibrated data aquired"

$\frac{50{,}000 \text{ mw}}{62.47 \text{ mw}} = 800$ units   units = n

C_2 1600

Cl_1 800

$\frac{25{,}000 \text{ mw}}{62.47 \text{ mw}} = 400$ units

C_2 800

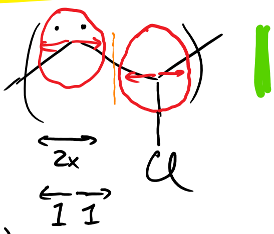
Cl_1 400

$\frac{75{,}000 \text{ mw}}{62.47 \text{ mw}} = 1{,}201$ unit

C_2 2,402

Cl 1,201

for the 50,000 mw peak.   radius 170 pm



$C_{radius} = 170 \text{ pm} \times 2 \times 1600$

$= 544{,}000$ pm (pico meter)

$= 5.44 \times 10^{-5}$ cm (centimeters)

$= 544$ nm

|← 544,000 pm →|

the polymer

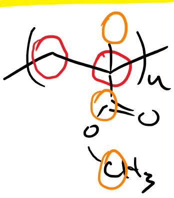
25,000 mw

272,000 pm

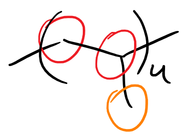
75,000 mw

816,680 pm

#5



poly methyl meth acrylate

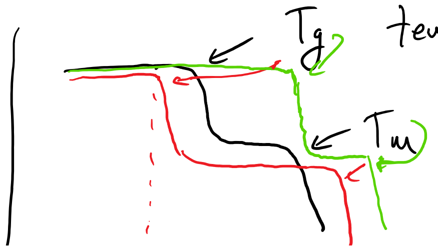


poly propylene

"tires"

~ -50°C

"physical property"



Tg temperature glass transition   if

Tm melting point   if 50°C Tg

"liquid phase"   if 100°C Tm

Polymers

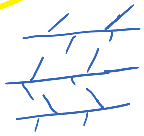
#1  poly ethylene

“a” $\xrightarrow{\text{1st step process}}$ “length of the polymer”

or?

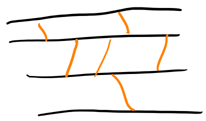
“shorter” or longer ?

“b” $\xrightarrow{\text{different 1st step process}}$  “b1”

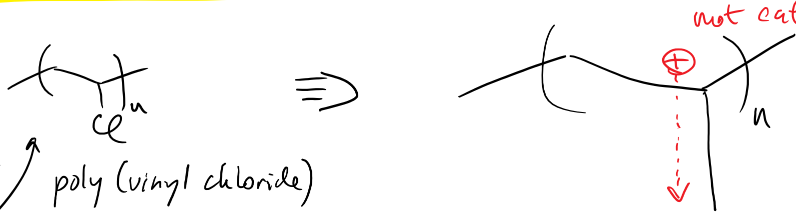
 or? ✓ “nano structure”

“change” or “b2”

“b3” “bigger”

“a” $\xrightarrow{\text{1st step}}$ $\xrightarrow{\text{2nd step}}$  “cross coupling”

also applies to #2 poly(propylene)

#3 

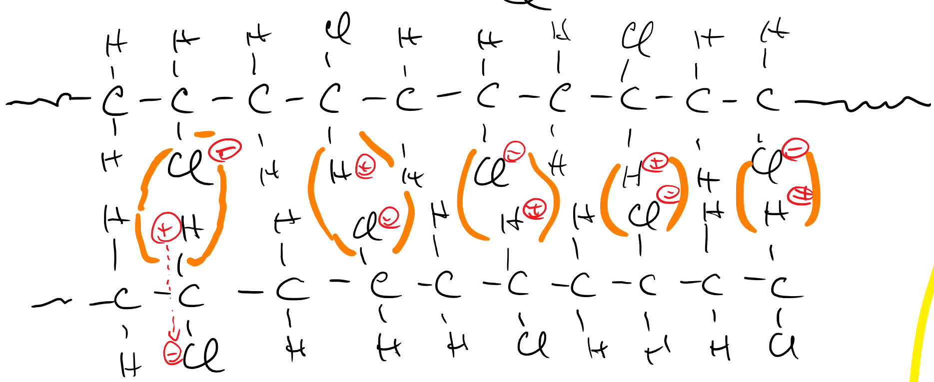
Cl=Cl

poly(vinyl chloride)

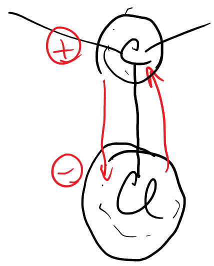
process#1

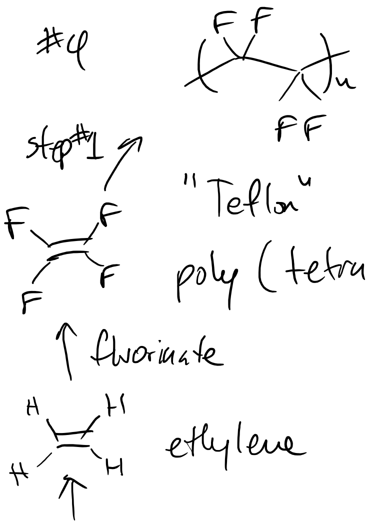
not cation

not anion



“symmetric”



#4 

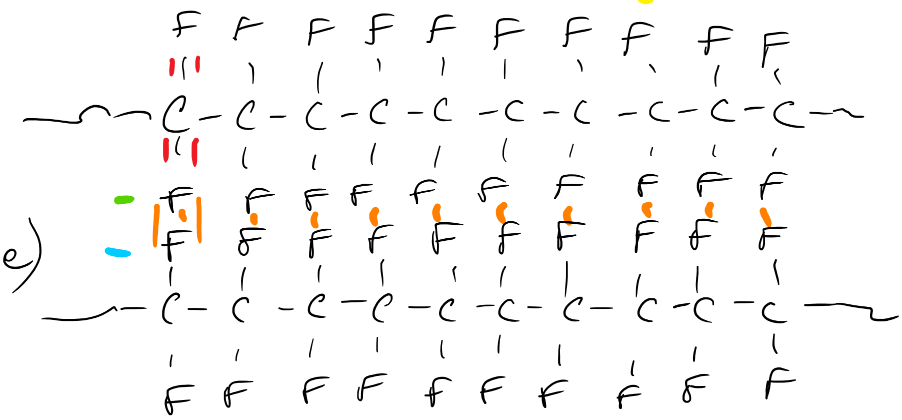
step#1

“Teflon”

poly(tetrafluoroethylene)

fluorinate

ethylene

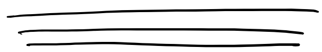


“good structure”

 ethylene

oil

"

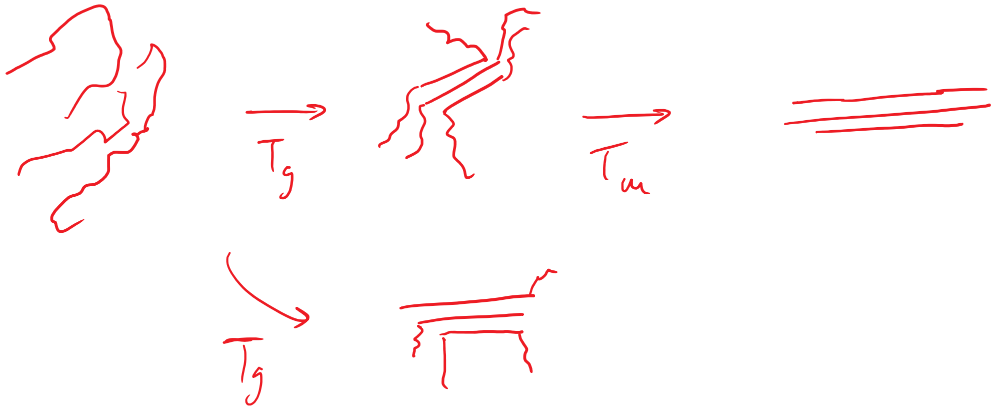
 "goal structure"

property

T(°C) temperature or (K)

"liquid phase"

it 100°C Tm



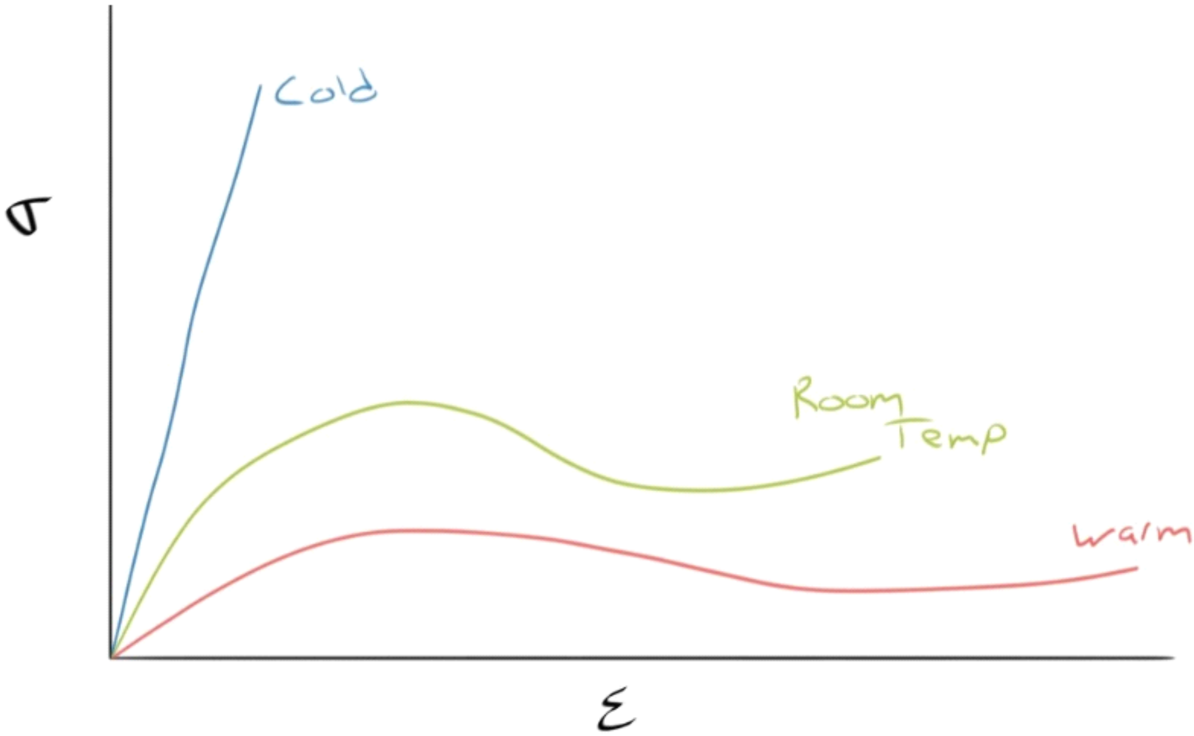


Figure 19. A stress-strain curve for a hypothetical plastic polymer at three temperatures. It is not uncommon for polymers to experience significant changes in mechanical properties with relatively small changes in temperature.

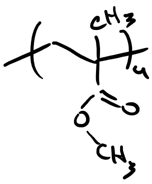
Figure 13. The molecular weight distribution for the hypothetical polymer sample in Figure 12. Our grouping into only five length groupings is very coarse and the actual distribution would be smooth, as shown by the nice smooth curve.

APS110H1f2024 October 25, 2024

October 23, 2024 4:16 PM

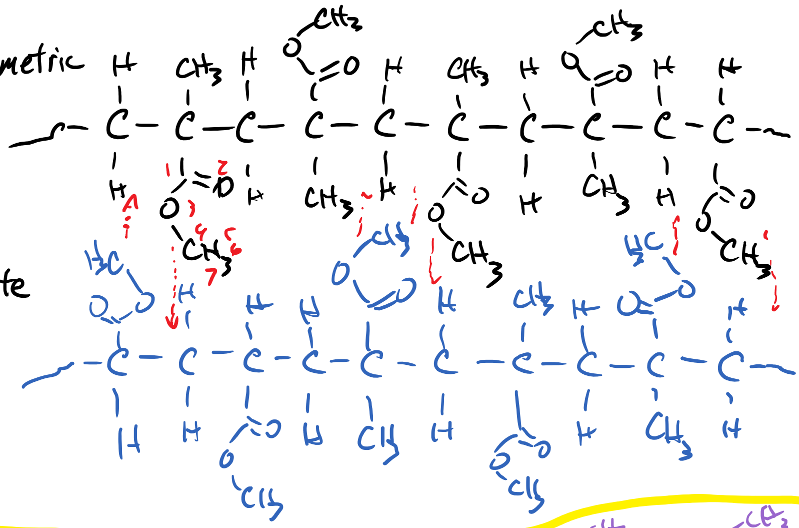
Polymers

#5



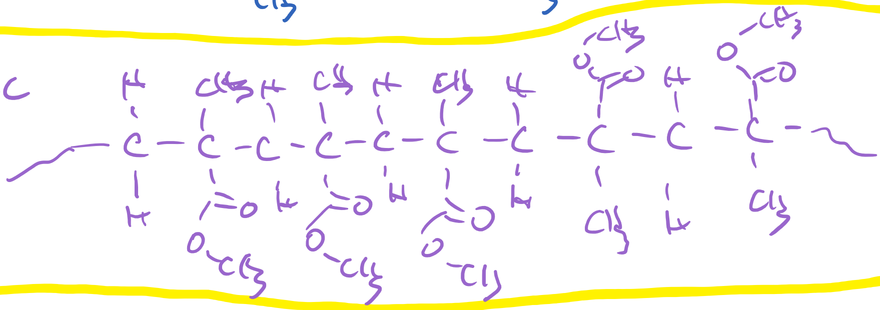
poly methyl meth acrylate

symmetric



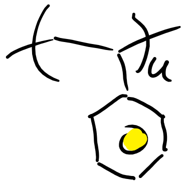
better mechanics

asymmetric



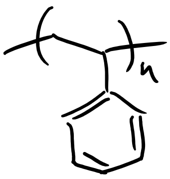
less

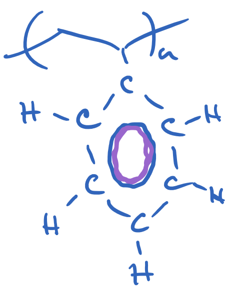
#6

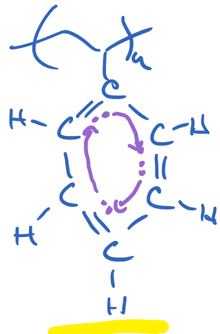


– aromatic ring

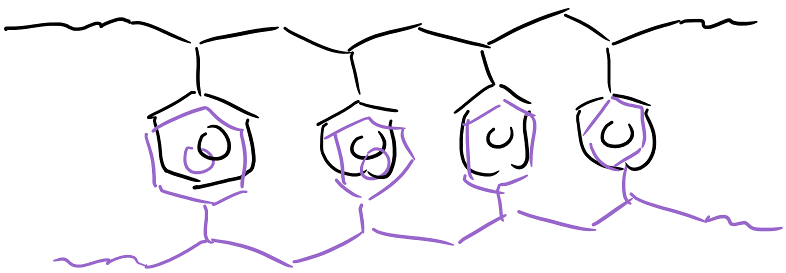
poly(styrene)







each length is the same



good mechanical

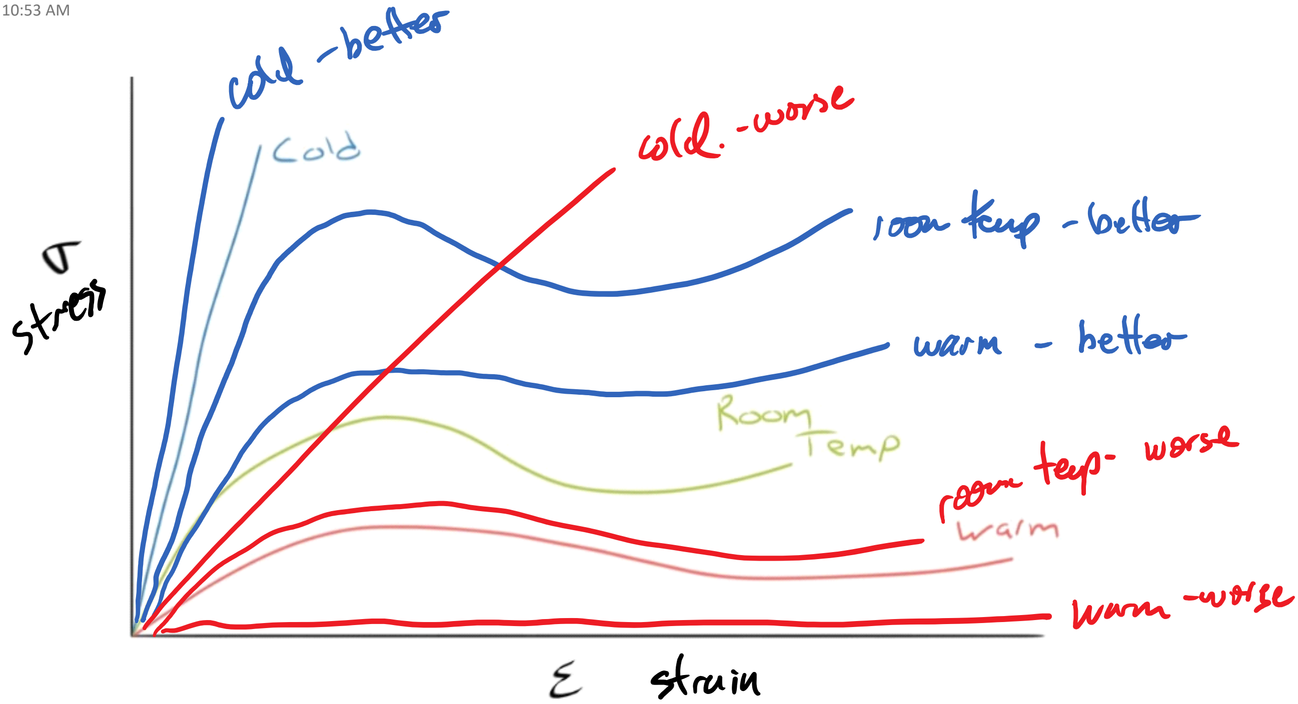
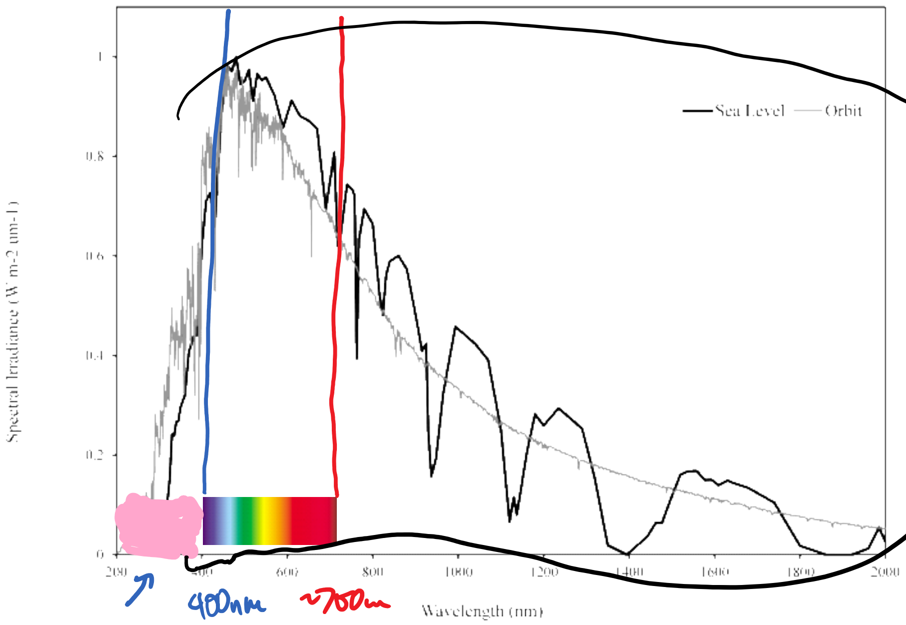


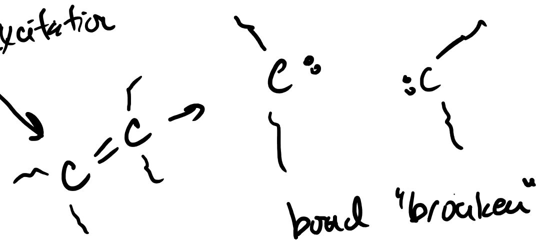
Figure 19. A stress-strain curve for a hypothetical plastic polymer at three temperatures. It is not uncommon for polymers to experience significant changes in mechanical properties with relatively small changes in temperature.



400nm ~700nm

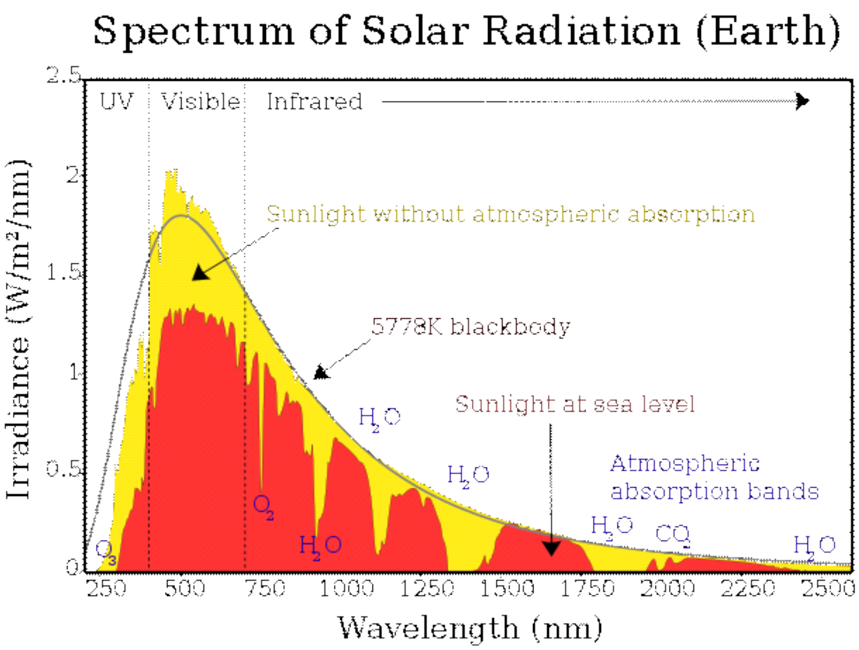
UV

excitation



bond "broken"

#1 + #6
UV absorption



end point of polymers

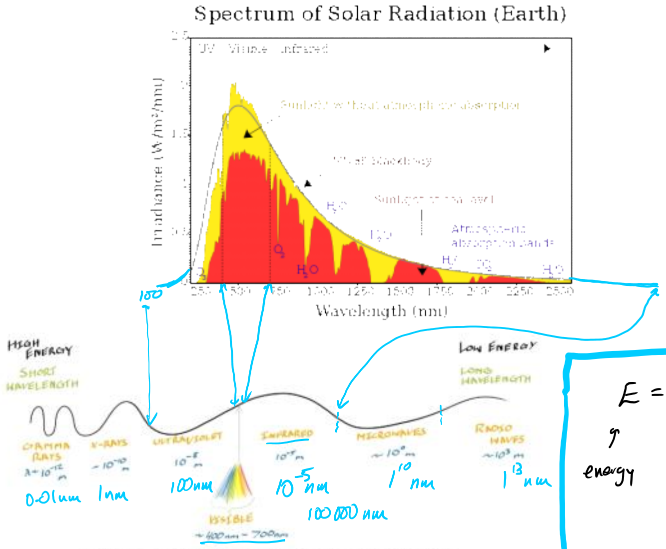
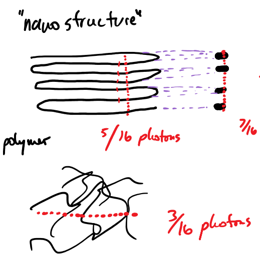
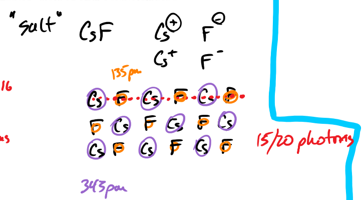
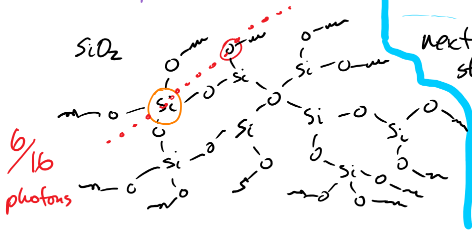


Figure 1. The electromagnetic spectrum. Visible light is only a tiny little bit of the spectrum.







$E = \frac{hc}{\lambda}$

energy

$h = 6.626 \times 10^{-34}$ J·s Planck constant

$c = 3 \times 10^{8} \frac{m}{s}$ speed of "light"

λ = wave length = 650 nm
$= 650 \times 10^{-9}$ m
$= 6.50 \times 10^{-7}$ m

$$= \frac{(6.626 \times 10^{-34}\,J\cdot\cancel{s})(3 \times 10^{8}\,\frac{\cancel{m}}{\cancel{s}})}{650 \times 10^{-9}\,\cancel{m}}$$

$E = 3.06 \times 10^{-19}$ J "electron charge energy"

J - electron charge

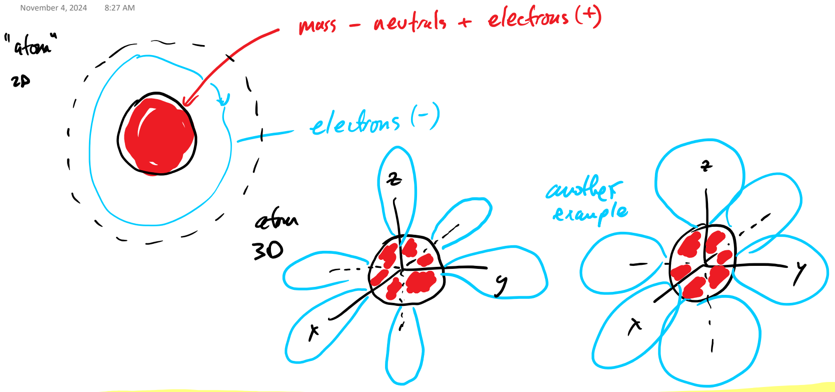
next step J → eV 1eV - 1 volt

$$1\,eV = E\,(1e^{-}\text{ through }1V) = 1.602 \times 10^{-19}\,C \cdot 1\,\frac{J}{C}$$
$$= 1.602 \times 10^{-19}\,\frac{J}{eV}$$

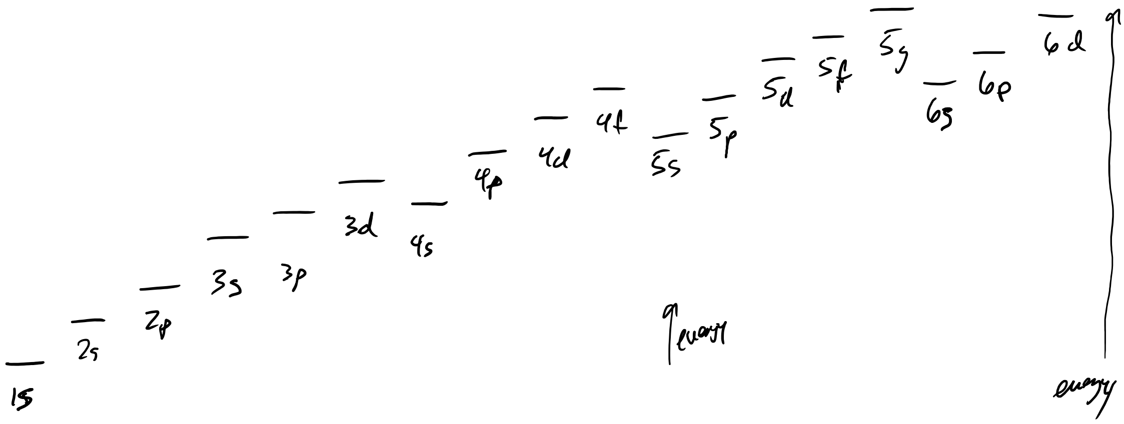
$$E = \frac{3.06 \times 10^{-19}\,J}{1.602 \times 10^{-19}\,\frac{J}{eV}} = 1.91\,eV$$

Electron/Electronic Configuration

November 4, 2024 8:27 AM

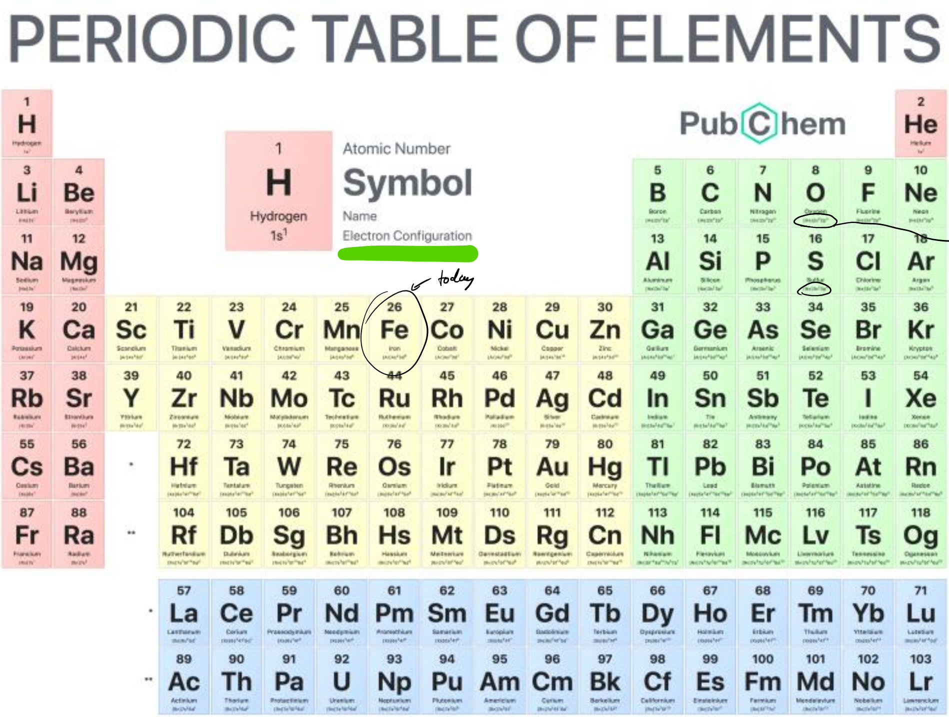


1s			
2s	2p		
3s	3p	3d	
4s	4p	4d	4f
5s	5p	5d	5f
6s	6p	6d	6f
7s	7p	7d	7f
8s	8p	8d	8f
2	6	10	14



Periodic Table - Electron Configuration

November 1, 2024 9:12 AM



$1s^2$

Neon - Ne

$[He]\,2s^2 2p^6 = 1s^2 2s^2 2p^6$

Oxygen $[He]\,2s^2 2p^4$

Argon - Ar $[Ne]\,3s^2 3p^6 = 1s^2 2s^2 2p^6 3s^2 3p^6$

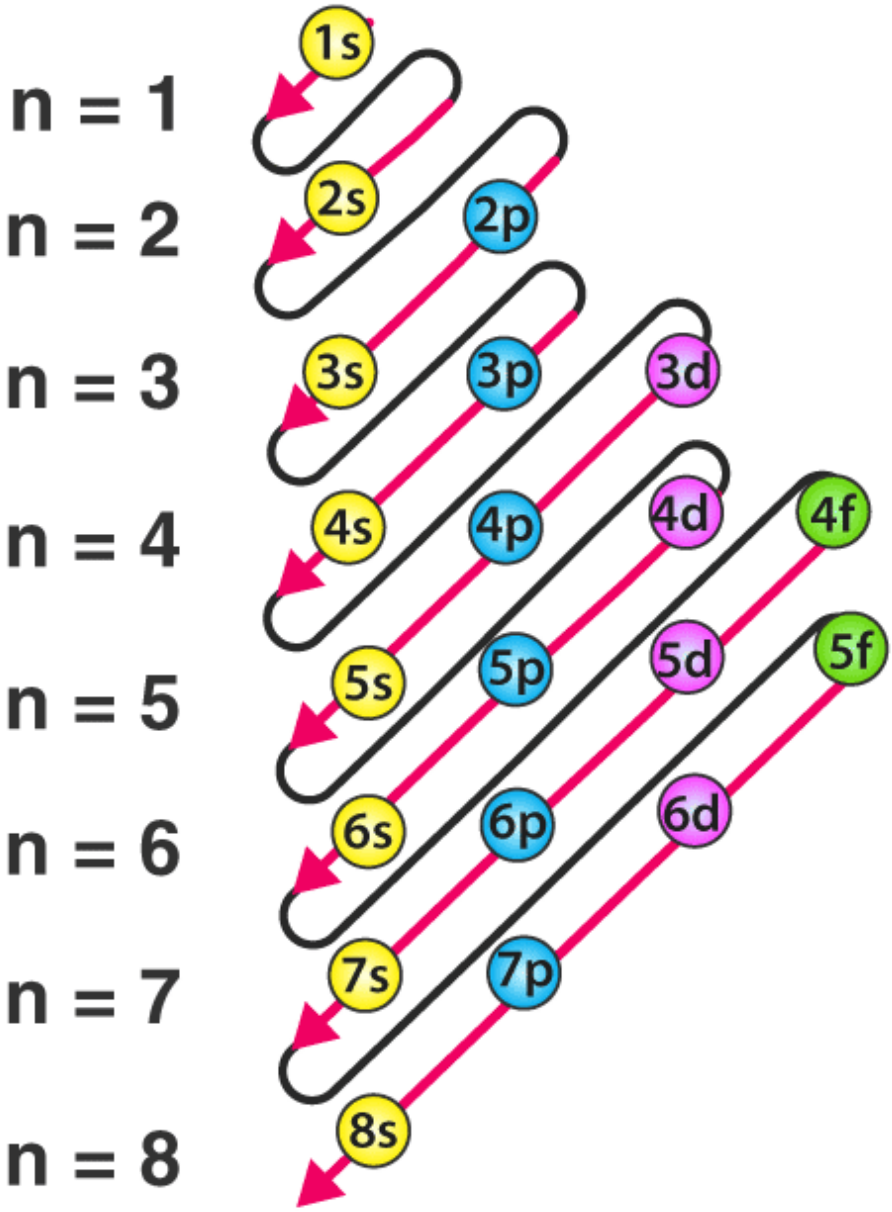
Krypton - Kr $[Ar]\,4s^2 3d^{10} 4p^6 = 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$

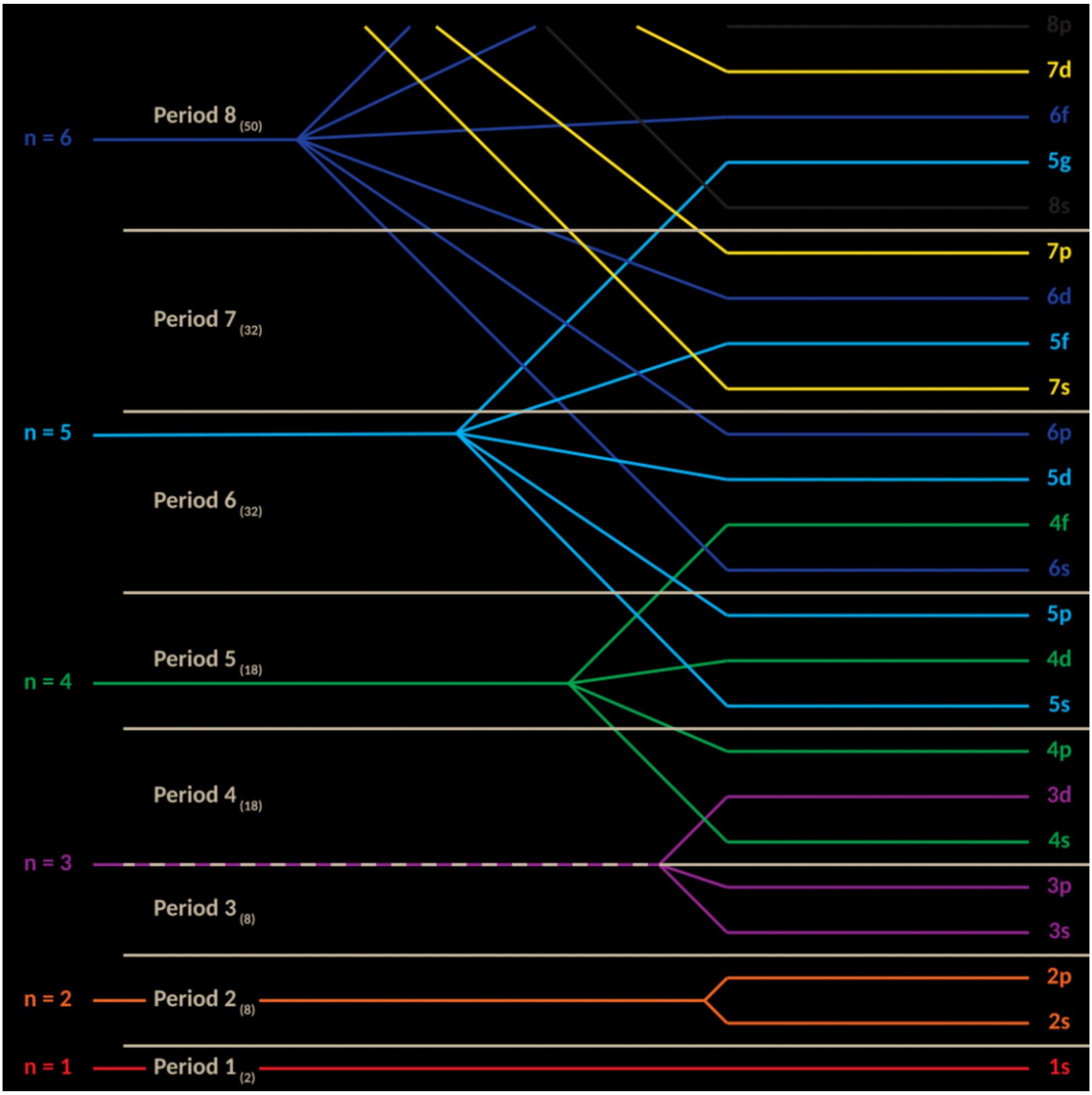
Xenon - Xe $[Kr]\,5s^2 4d^{10} 5p^6$

Radon - Rn $[Xe]\,6s^2 4f^{14} 6d^{10} 6p^6$

Oganesson - Og $[Rn]\,7s^2 7p^6 5f^{14} 6d^{10}$

November 4, 2024 8:24 AM



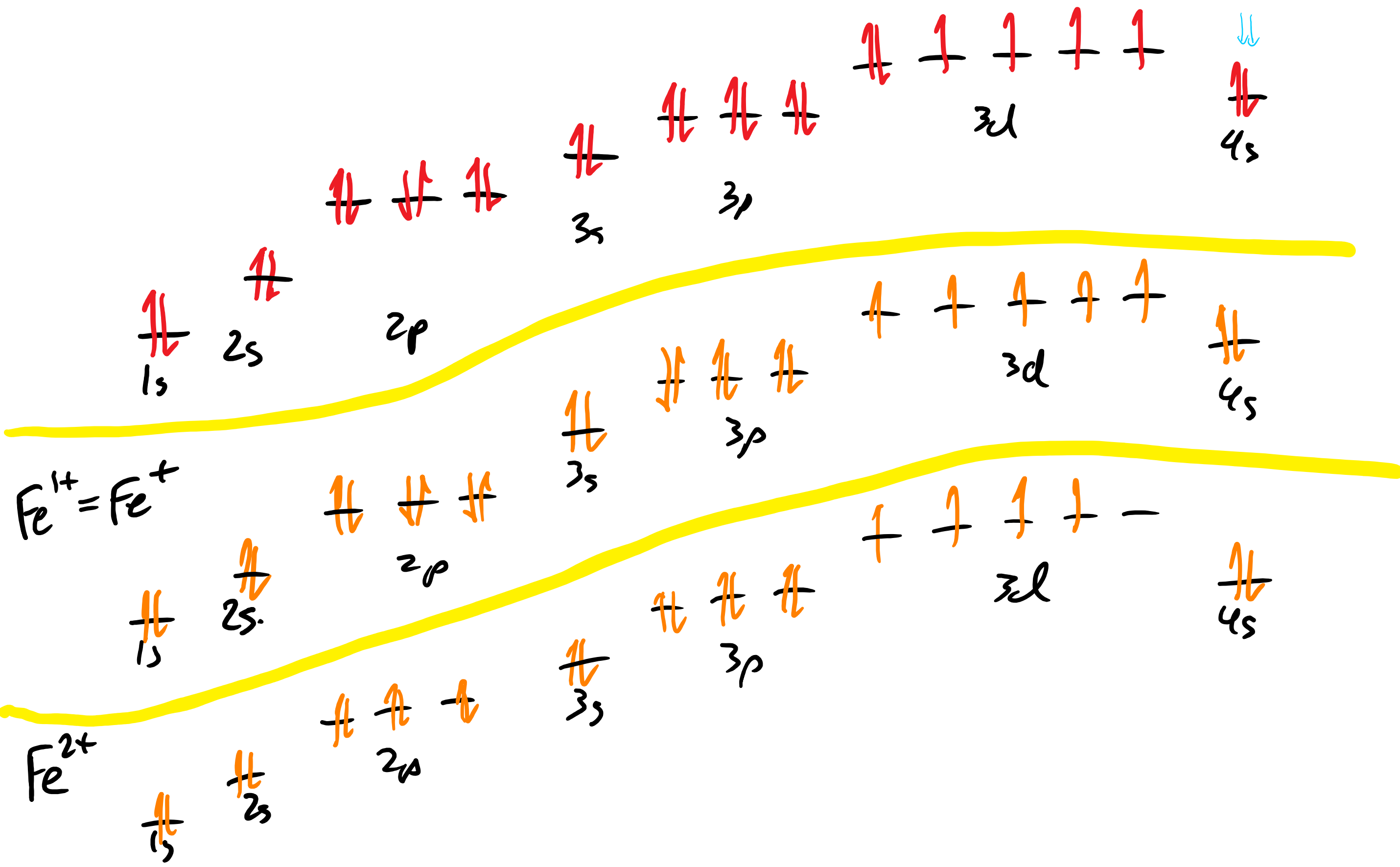


8p
7d
Period 8 (50)
n = 6
6f
5g
8s
7p
Period 7 (32)
6d
5f
7s
n = 5
6p
5d
Period 6 (32)
4f
6s
5p
Period 5 (18)
n = 4
4d
5s
4p
Period 4 (18)
3d
4s
n = 3
3p
Period 3 (8)
3s
n = 2
Period 2 (8)
2p
2s
n = 1
Period 1 (2)
1s

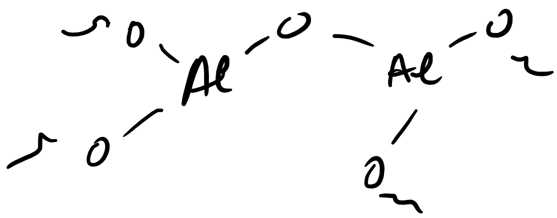
energy

Iron (Fe) - example

$Fe = [Ar]\, 4s^2 3d^6 = 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$



Al_2O_3

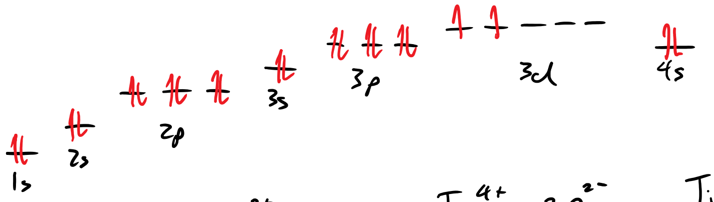


CsF

$Cs^+ \quad F^-$

Electron/Electronic Configuration

titanium (Ti) $[Ar]\, 4s^2\, 3d^2 = Ti^0$



$Cl^0\ [Ne]\, 3s^2 3p^5$

$Cl^-\ [Ne]\, 3s^2 3p^6$

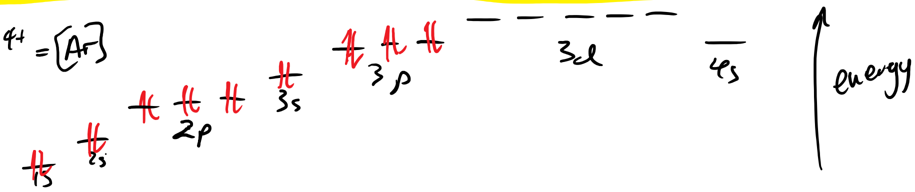
$Ti^{2+} + O^{2-} \to TiO$

$Ti^{4+} + 2O^{2-} \to TiO_2$

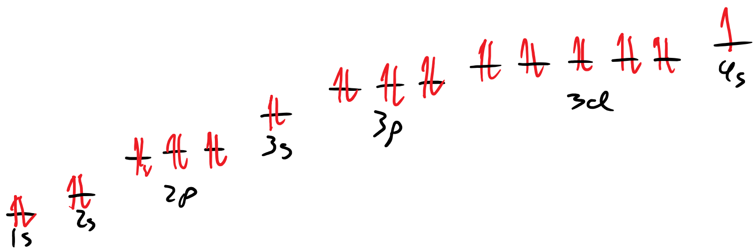
$Ti^{4+} + 4Cl^- \to TiCl_4$

$TiCl_4 \xrightarrow{2H_2O} TiO_2 + 4HCl\,(gas)$

$Ti^{4+} = [Ar]$



Copper (Cu) $[Ar]\, 4s^1\, 3d^{10}$

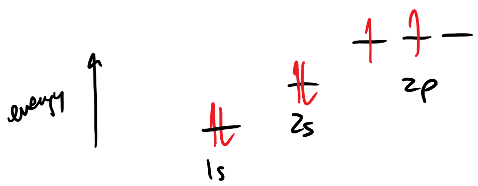


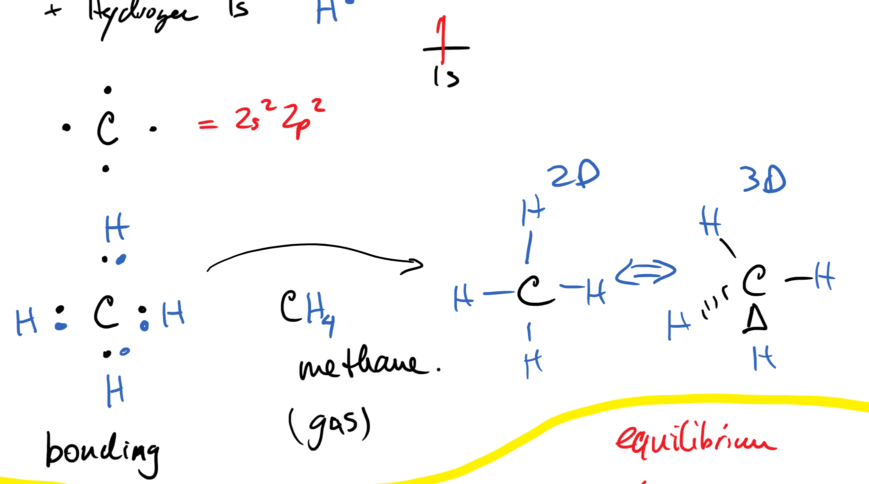
thermodynamic difference.

Carbon (C) $[He]\, 2s^2\, 2p^2$

$= 1s^2\, 2s^2\, 2p^2$

+ Hydrogen $1s^1$ H•

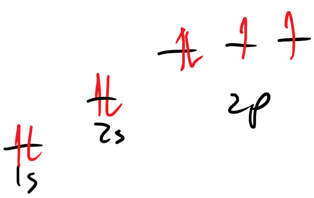


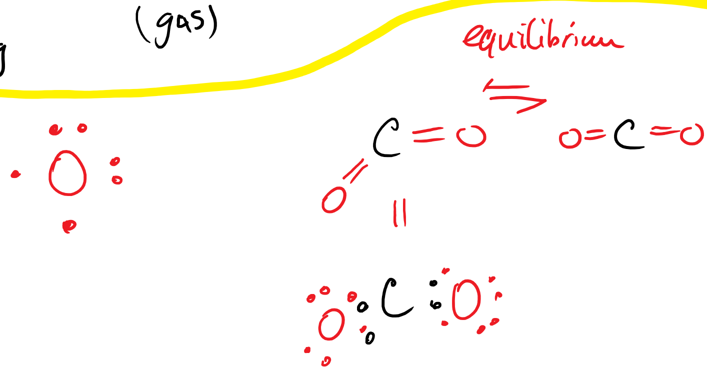


Carbon dioxide CO_2

oxygen

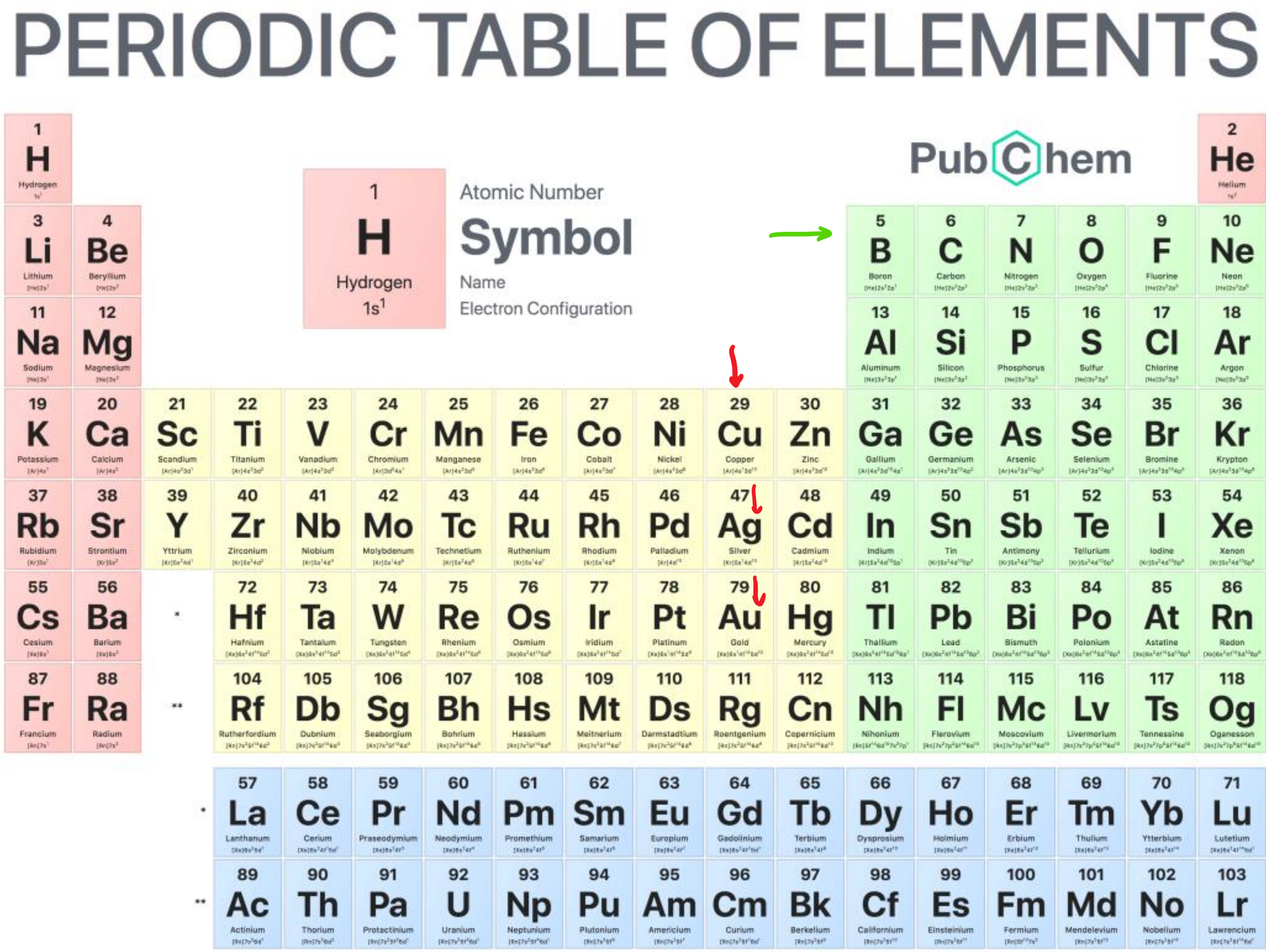
$[He]\, 2s^2 2p^4$





Periodic Table - Electron Configuration

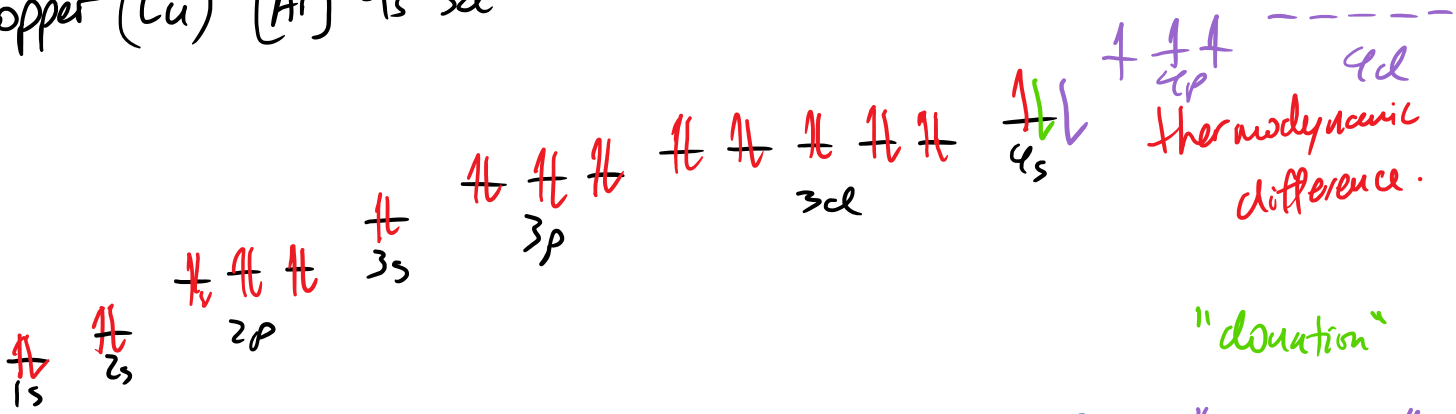
November 8, 2024 2:00 PM



APS110H1f2024 November 11, 2024

November 11, 2024 8:43 AM

Copper (Cu) [Ar] $4s^1 3d^{10}$

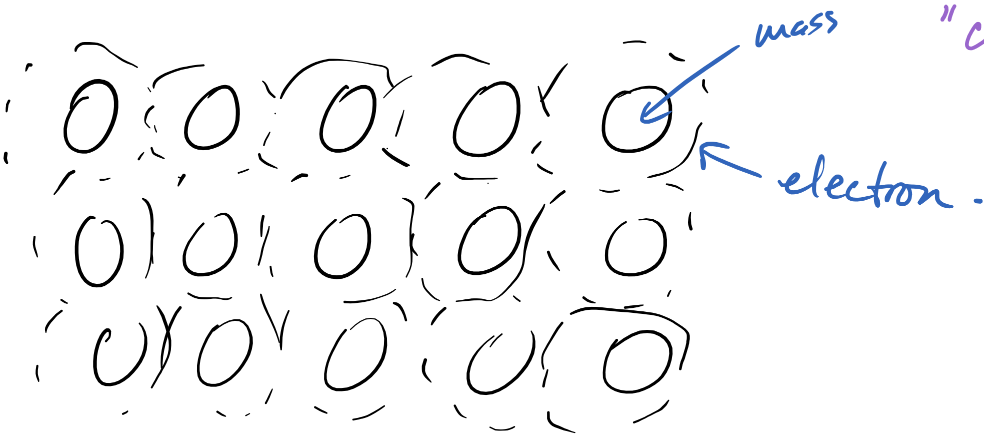


thermodynamic difference.

"donation"

"conductivity"

140pm



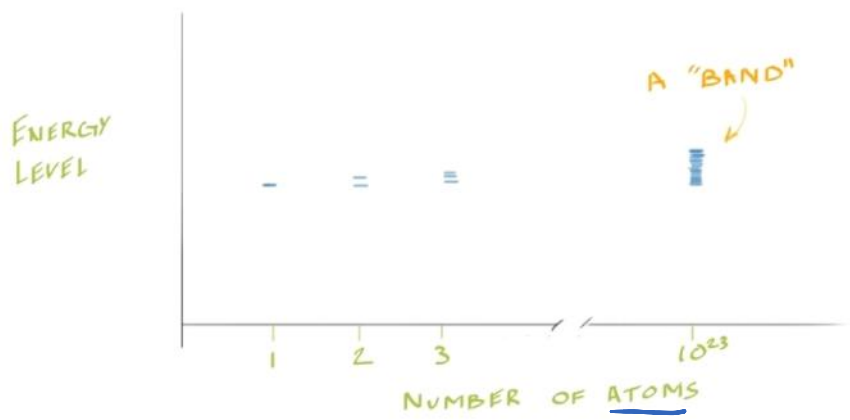
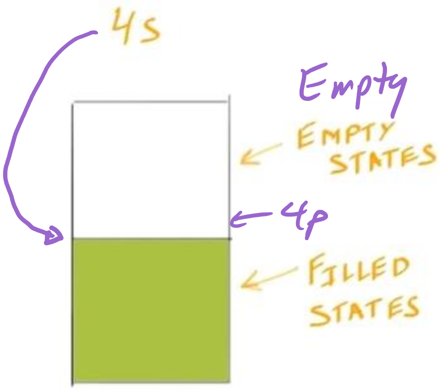


Figure 11. A schematic depiction of a particular energy level in an isolated atom, two atoms, three atoms, and so on up to a massive collection of atoms, as in a solid. The number of energy levels in a solid, for a corresponding single energy level in an isolated atom, is equal to the number of atoms, so that when we have a solid there are so many closely spaced energy levels as to be essentially continuous. We call this a band.



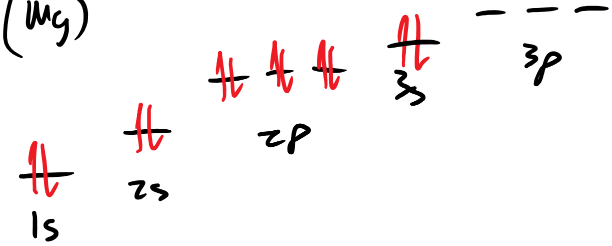
energy levels

Figure 12. The band structure for copper.

Magnesium, Aluminum

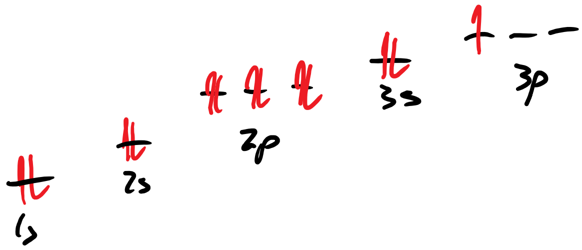
November 11, 2024 8:54 AM

Magnesium (Mg) $[Ne]\ 3s^2 = 1s^2 2s^2 2p^6 3s^2 = Mg^0$



electric conductivity
- weak / not good
- semi-conductor

Aluminum (Al) $[Ne]\ 3s^2 3p^1 = Al^0$



electric conductivity (back in the day)
- "ok" conductivity

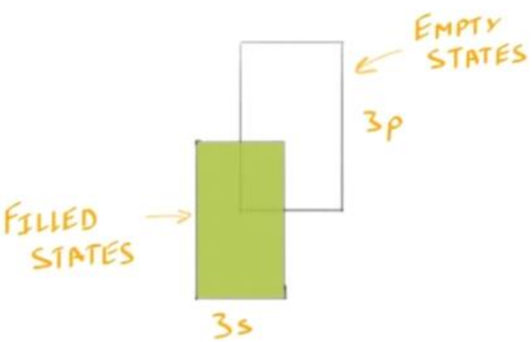


Figure 13. The band structure for magnesium.

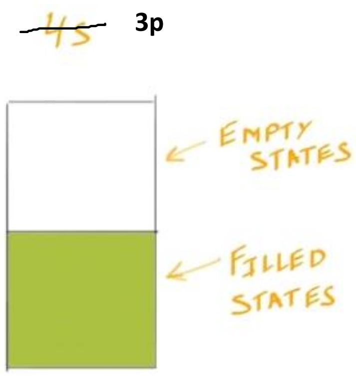


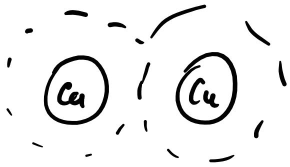
Figure 12. The band structure for ~~copper~~ aluminum

Metal, Salts... Octet rule

November 11, 2024 10:48 AM

≈ 8

Octet rule "$ns^2\ np^6$" − "stable"/more stable

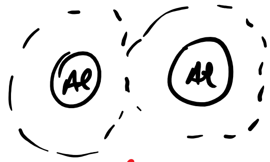


copper

$\sim 4s^1\ 3d^{10}$

$\sim 3p^6\ 4s^1 \sim \quad \sim 3p^6\ 4s^2 \sim$

donation



$\sim \cancel{\uparrow\downarrow}\ \uparrow - -$

3s 3p

3+3 = 6

↑

donated

chlorine (Cl) $[Ne]\ 3s^2 3p^5 \xrightarrow{Cl^-} [Ne]\ 3s^2 3p^6$

fluorine (F) $[He]\ 2s^2 2p^5 \xrightarrow{F^-} [He]\ 3s^2 3p^6$

bromine (Br) $[Ar]\ 4s^2 3d^{10} 4p^5 \xrightarrow{Br^-} [Ar]\ 4s^2 3d^{10} 4p^6$

iodine (I) $[Kr]\ 5s^2 4d^{10} 5p^5 \xrightarrow{I^-} [Kr]\ 5s^2 4d^{10} 5p^6$

potassium (K) $[Ar]\ 4s^1$

$= 1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 \xrightarrow{K^+} 1s^2 2s^2 2p^6 3s^2 3p^6$

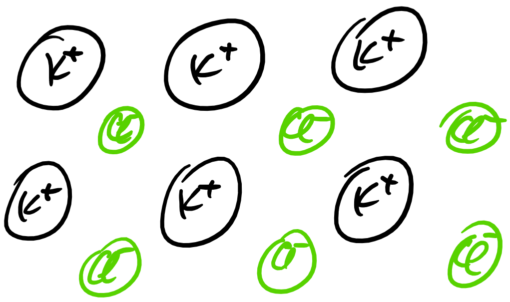
calcium (Ca) $= [Ar]\ 4s^2$

$= 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 \xrightarrow{Ca^{2+}} 1s^2 2s^2 2p^6 3s^2$

175 pm

KCl

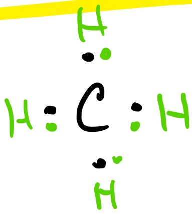
275 pm



H

H : C : H

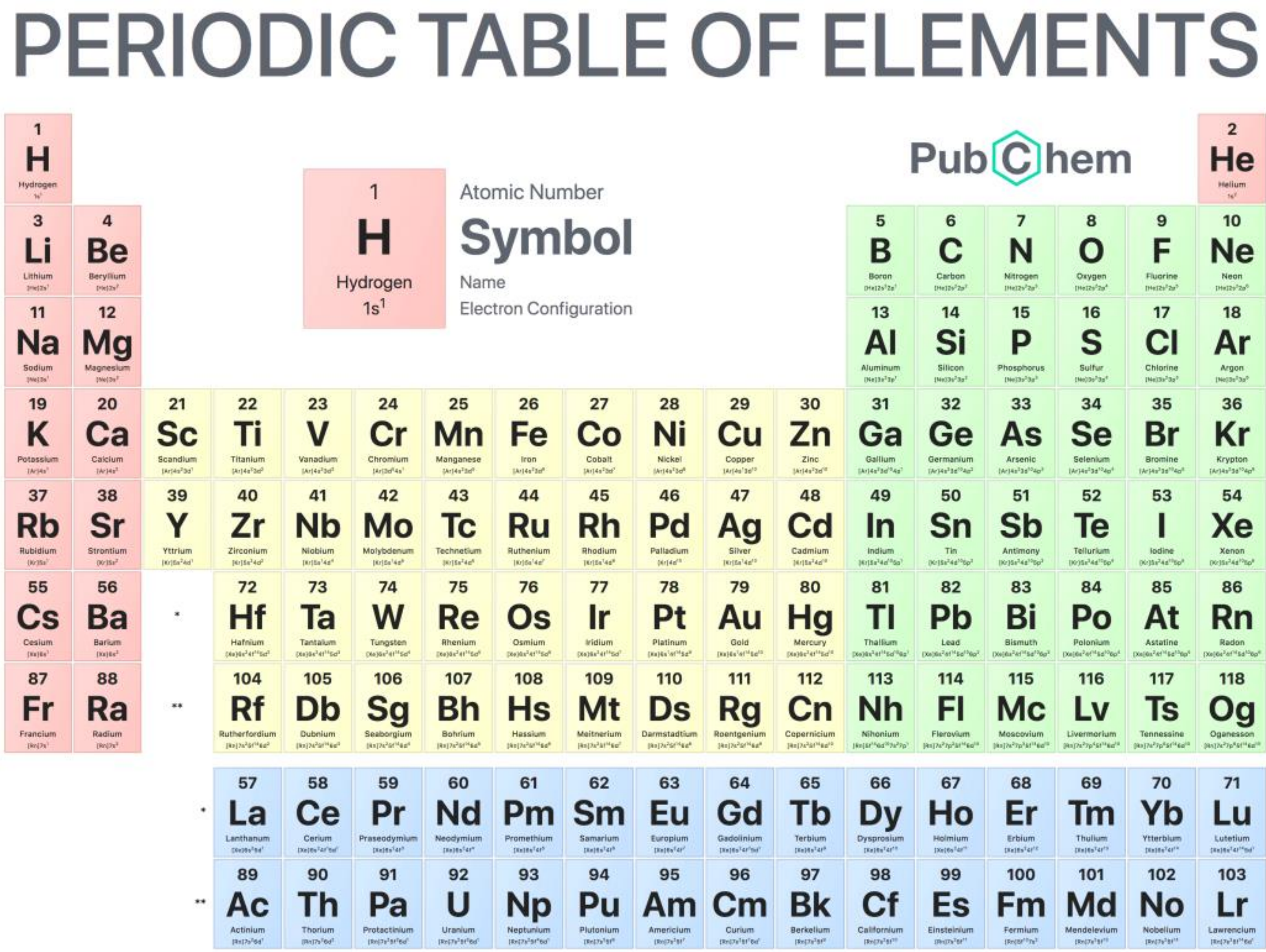
C $1s^2\ 2s^2\ 2p^2 \xrightarrow[H]{4} 1s^2 2s^2 2p^6$



C $1s^2 2s^2 2p^2 \xrightarrow[H]{4} 1s^2 2s^2 2p^6$

Periodic Table - Electron Configuration

November 8, 2024 2:00 PM



Periodic Table - Electron Configuration

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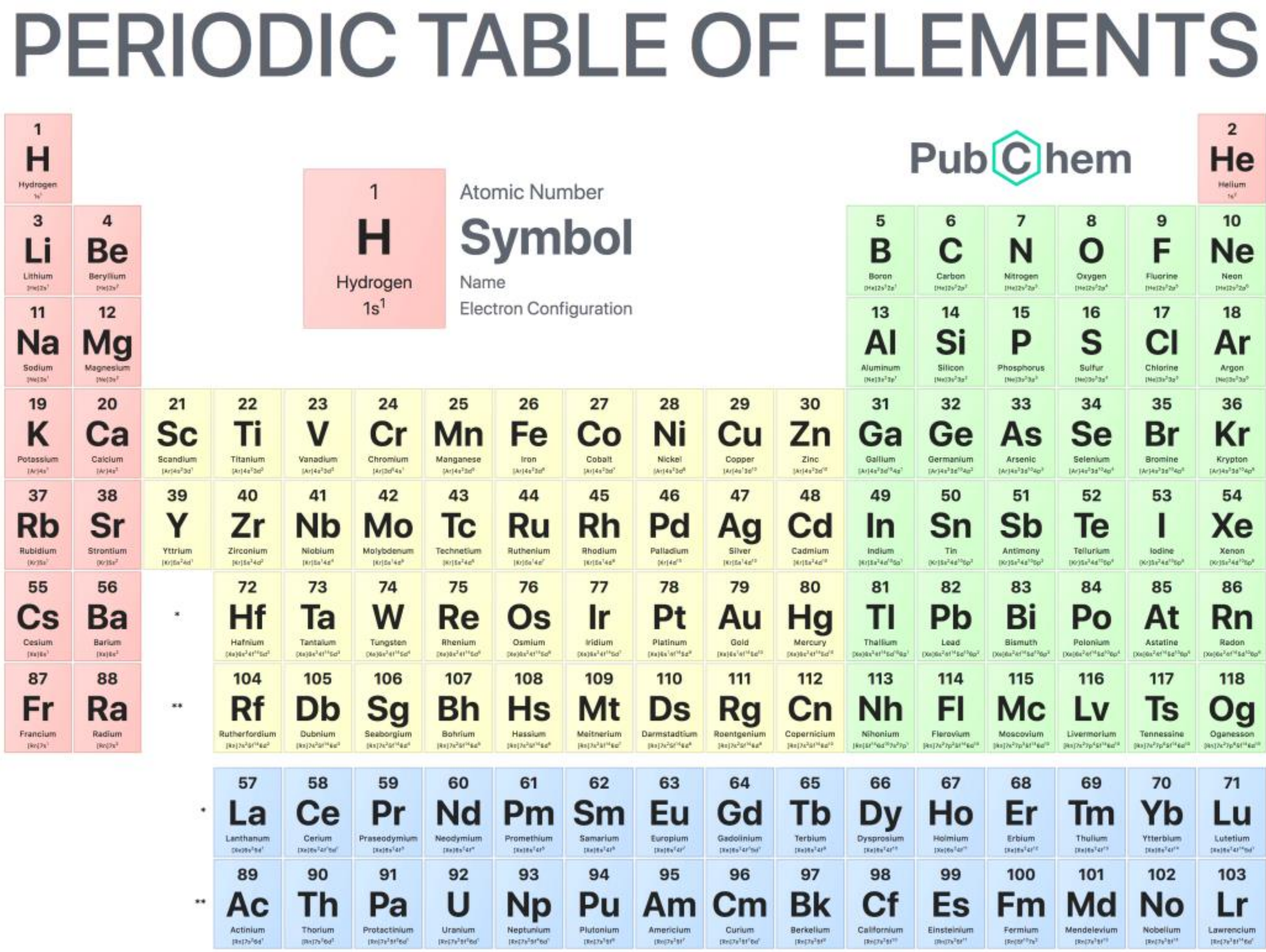

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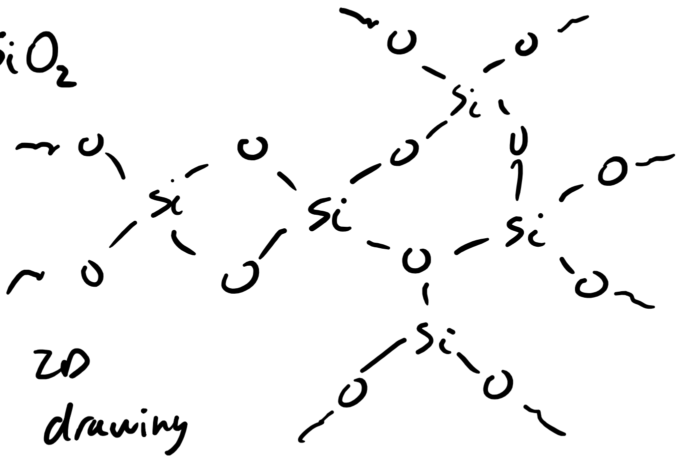
November 12, 2024 8:09 AM

Cu^{2+} O^{2-}

Insulators - ceramics - Al_2O_3 SiO_2 CuO TiO_2

- $AlCl_3$

SiO_2



2D drawing

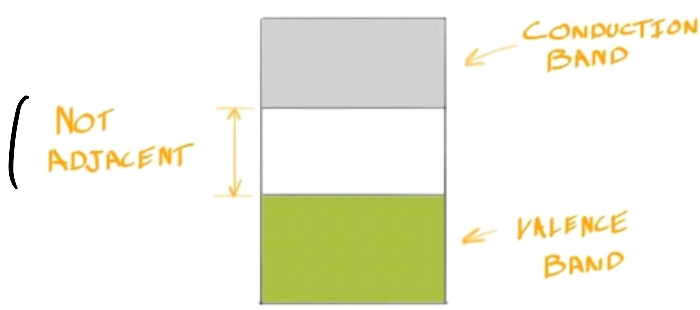


Figure 14. The band structure for an insulator, showing the valence and conduction bands with a large gap between them

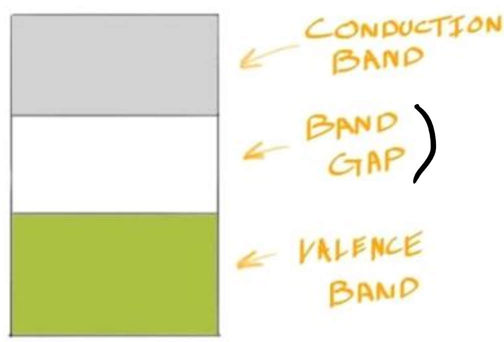
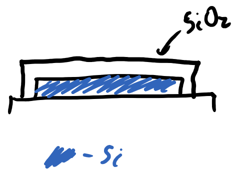


Figure 15. The band structure for an insulator, with the band gap identified as well as the valence and conduction bands.

Semiconductors

November 11, 2024 9:10 AM

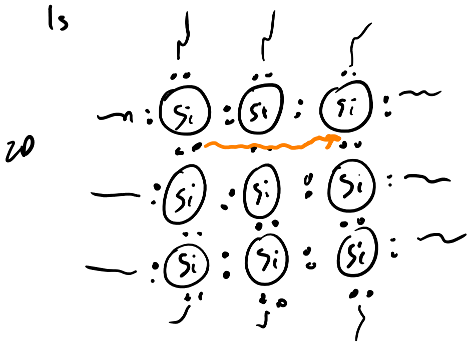


silicon

Si [Ne] $3s^2 3p^2$

$= 1s^2 2s^2 2p^6 3s^2 3p^2$

1s 2s 2p 3s 3p



sp^3 hybrids

sp^3 hybridization

"donated"

3s 3p

only when bonded.

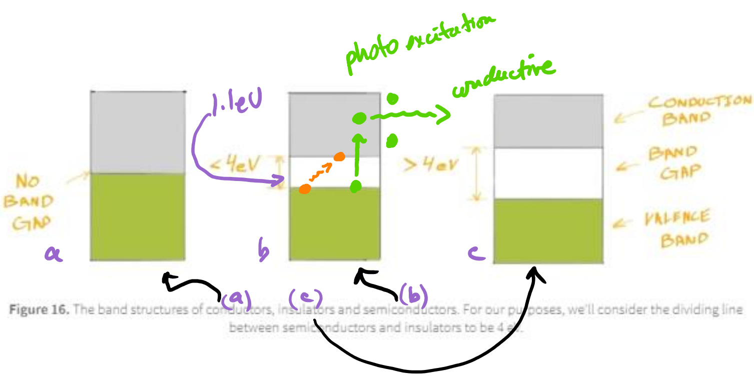


Figure 16. The band structures of conductors, insulators and semiconductors. For our purposes, we'll consider the dividing line between semiconductors and insulators to be 4 eV.

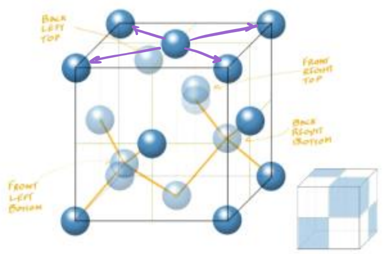
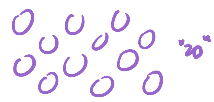
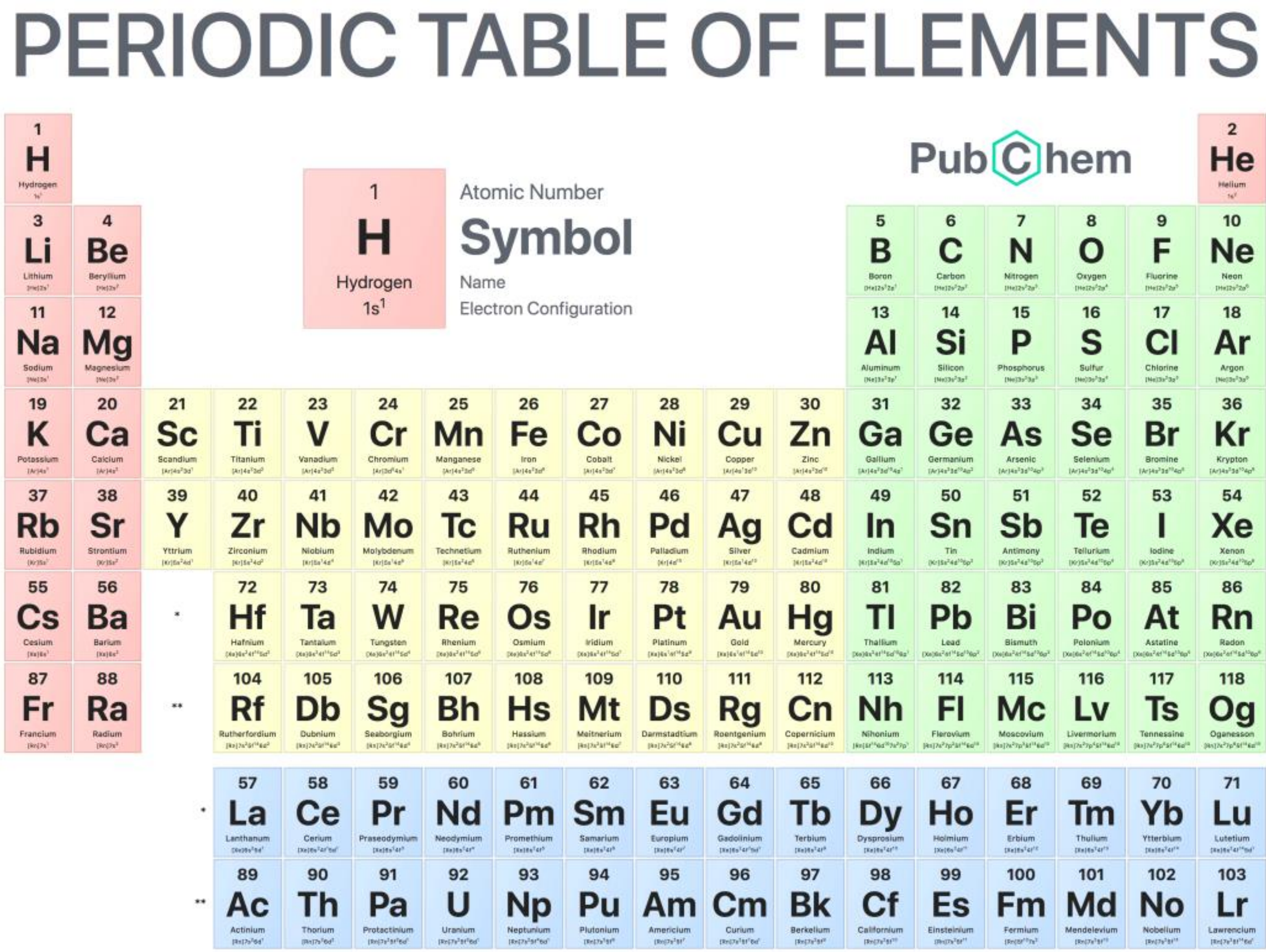


Figure 19. The structure of diamond cubic. This structure can be thought of as an FCC lattice of atoms with the same atoms occupying half of the available tetrahedral interstitial sites, in alternating positions. The alternating positions are illustrated with the shaded "sub-cube" faces in the second cube.



Periodic Table - Electron Configuration

November 8, 2024 2:00 PM



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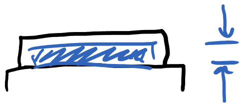
November 15, 2024 1:53 PM

Dopants (Extrinsic) - to the semiconductors

Si



0.2-0.5 mm → Q? found?

n-type - more electron(s)

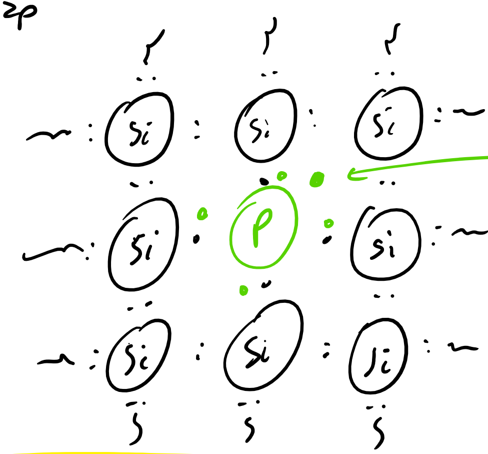
P - phosphorous

[Ne] $3s^2\ 3p^3$

1s 2s 2p 3s 3p

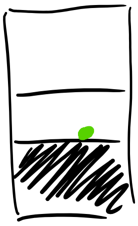
P = Si

low molar ratio



extra electron

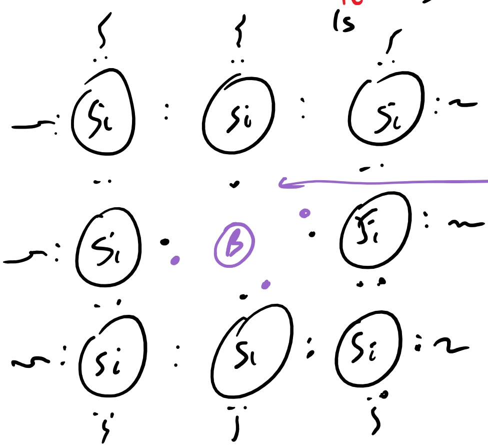
gap →



p-type Boron (B) [He] $2s^2\ 2p^1$

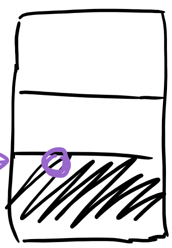
1s 2s 2p 3s 3p

→ adding electron present



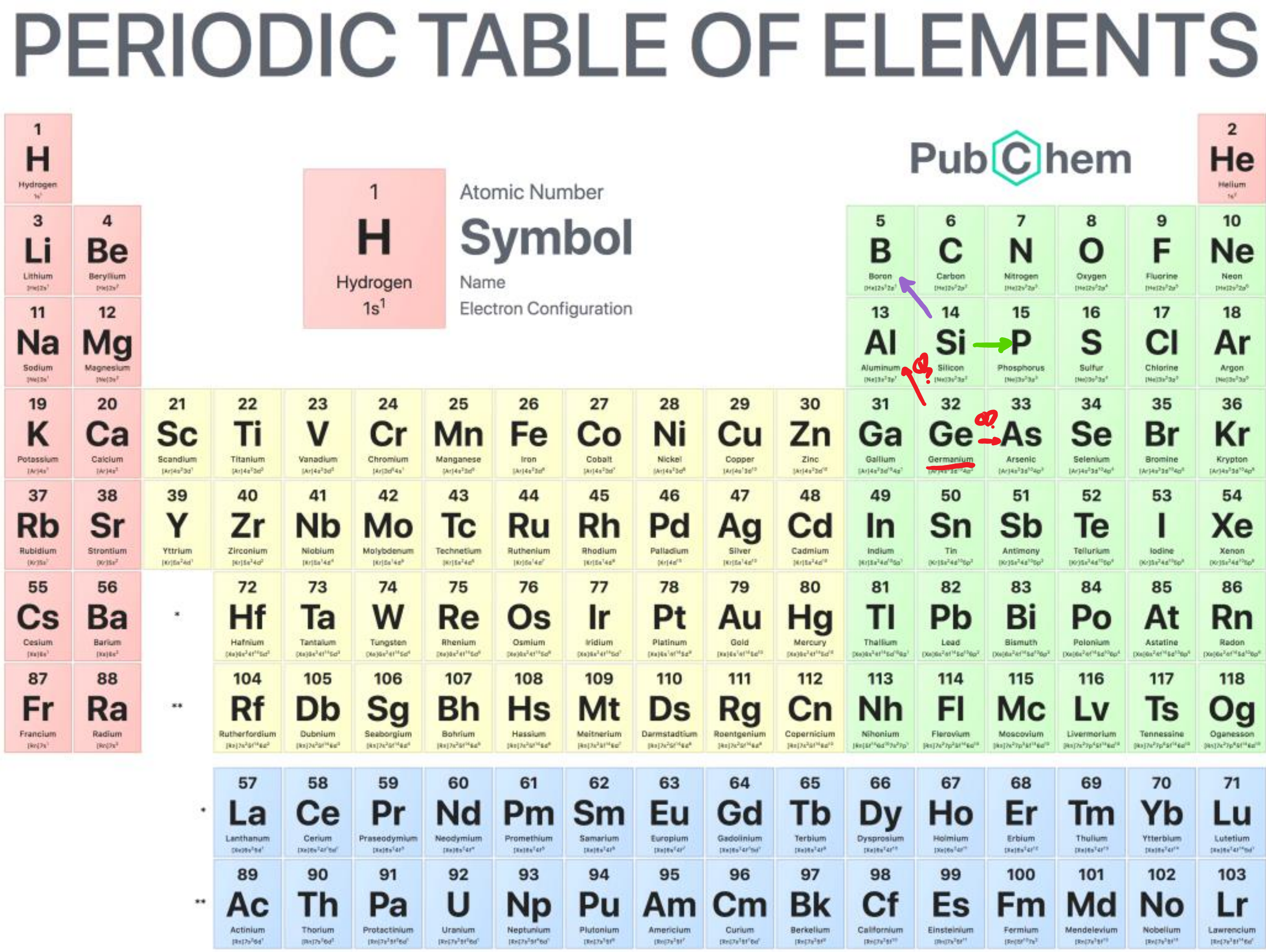
missing an electron

accept electrons. →



Periodic Table - Electron Configuration

November 8, 2024 2:00 PM



APS110H1s2024 November 18, 2024

November 18, 2024 10:33 AM

Reminder :-): September 18 --> September 27 - applies to conductors and semi-conductors

Book Section 9:

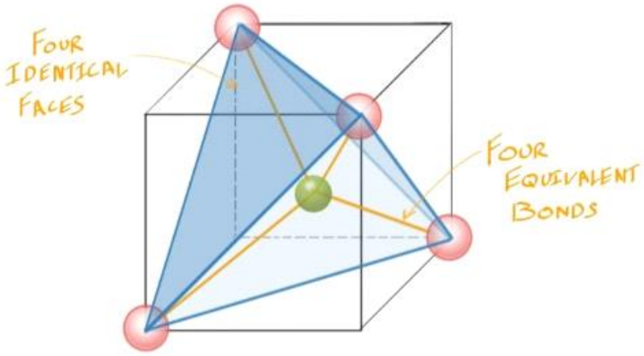


Figure 18. The tetrahedral interstitial site at the centre of a cube. Note that the coordination number is also 4, in addition to the number of faces on the solid formed by this site, however the name comes from the solid geometry, not the coordination number.

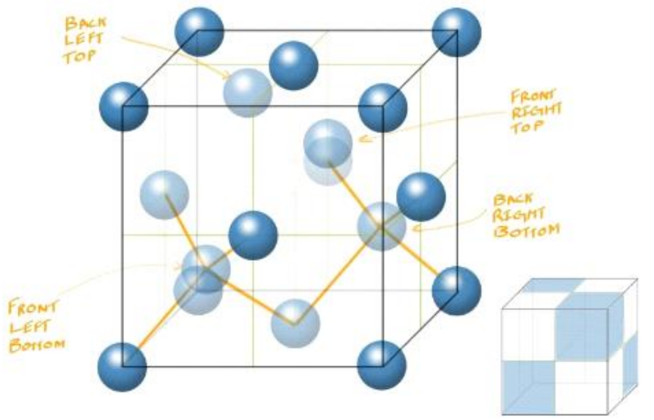


Figure 19. The structure of diamond cubic. This structure can be thought of as an FCC lattice of atoms with the same atoms occupying half of the available tetrahedral interstitial sites, in alternating positions. The alternating positions are illustrated with the shaded "sub-cube" faces in the second cube.

Calculations link:

https://can01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fyoutu.be%2FHmR9vfLk5-E&data=05%7C02%7Ctim.bender%40utoronto.ca%7C403a272b50f0498ee98f08dd07e3e7be%7C78aac2262f034b4d9037b46d56c55210%7C0%7C0%7C638675397604841544%7CUnknown%7CTWFpbGZsb3d8eyJFbXB0eU1hcGkiOnRydWUsIlYiOiIwLjAuMDAwMCIsIlAiOiJXaW4zMiIsIkFOIjoiTWFpbCIsIldUIjoyfQ%3D%3D%7C0%7C%7C%7C&sdata=0gZDFaFGt3unIeV80ZptmCjaTddjRf7vEQmyrPIOt5w%3D&reserved=0

Thermodynamics

November 18, 2024 10:33 AM

(a) Na^{0} = separated.

+1 electron

"process"

$Na^{\oplus} X^{\ominus}$

in our "land"

+ $\frac{1}{2} Cl_2 \rightleftharpoons Cl^{0}$

"gas"

"toxic"

$Cl^{\ominus}$

−1 electron

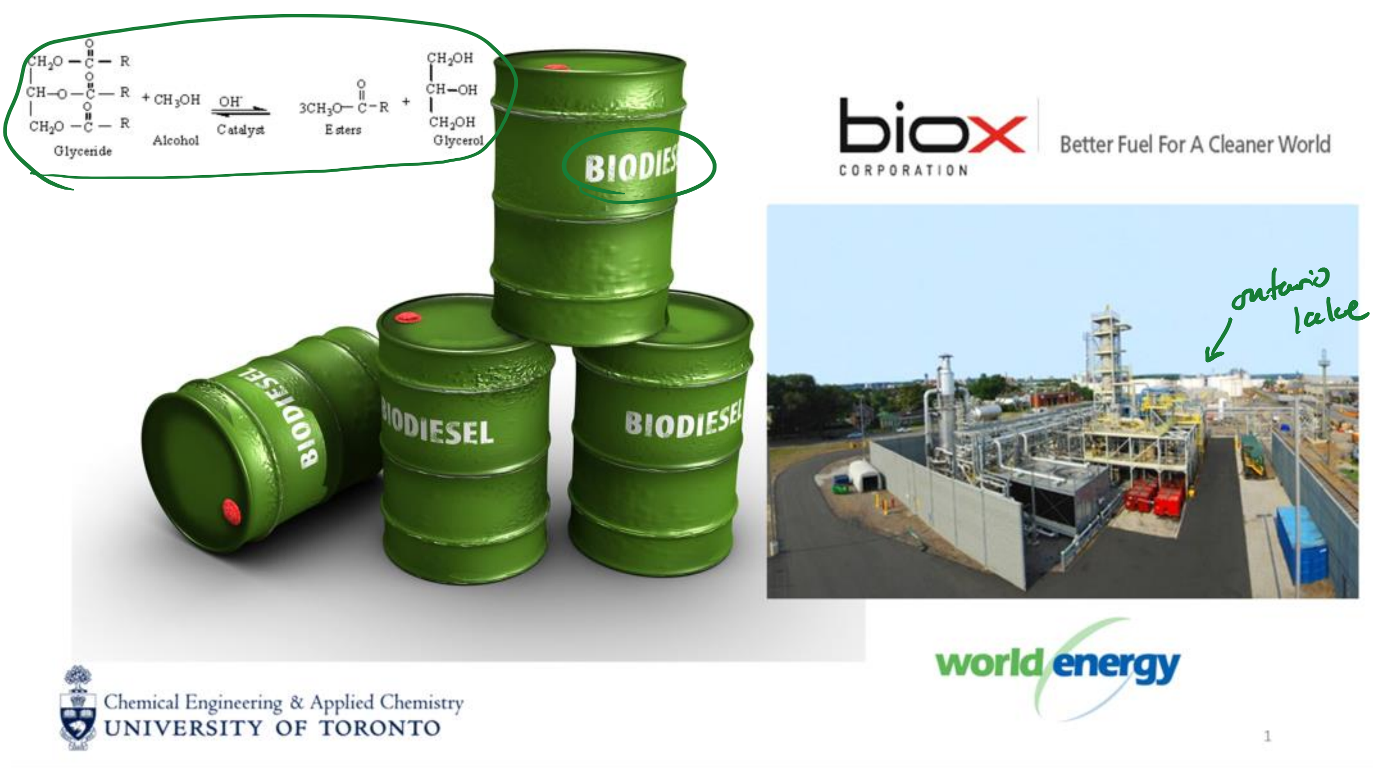
+ separation

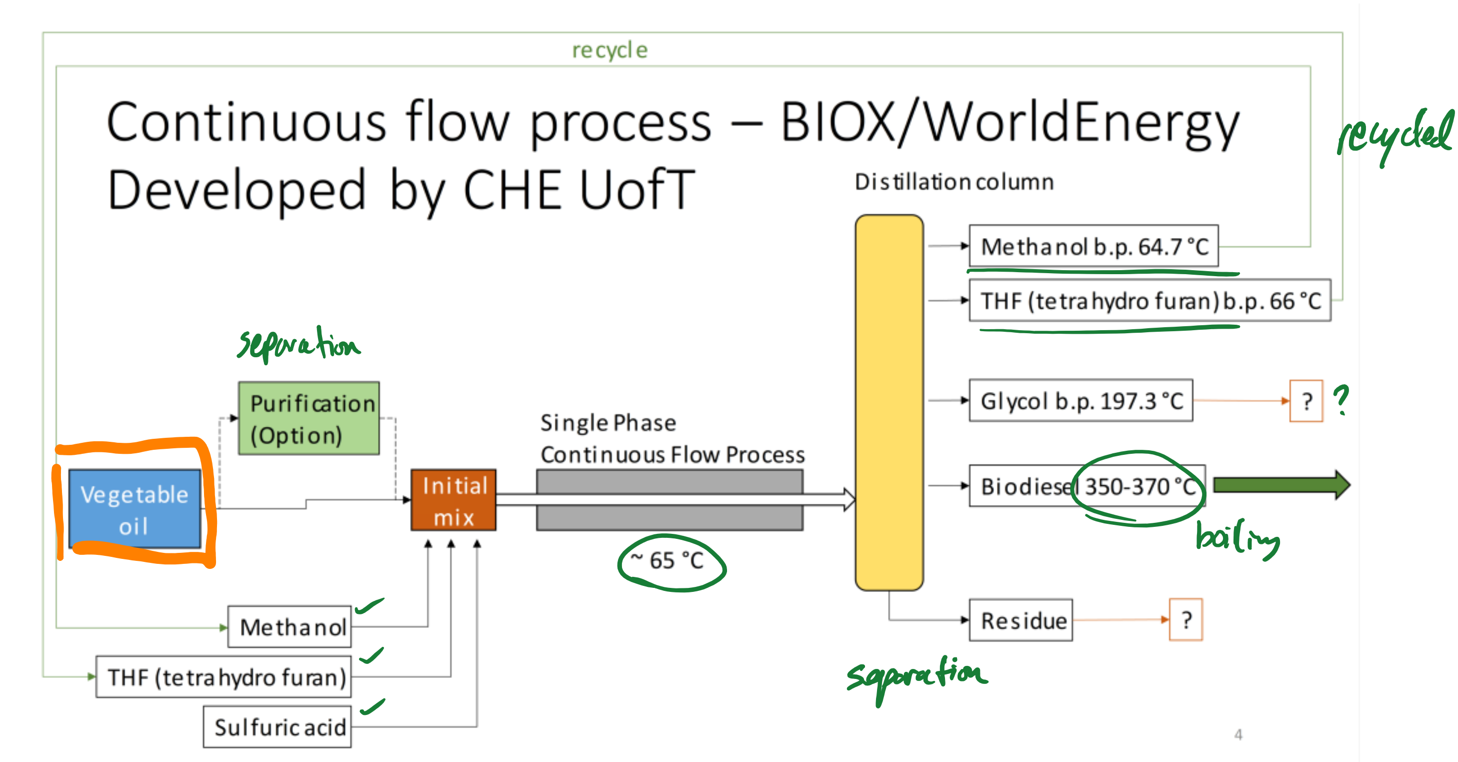
$Na^{\oplus}\ Cl^{\ominus}$

+ "energy"

Biofuels

November 18, 2024 11:02 AM





APS110H1f2024 November 20, 2024

November 19, 2024 2:47 PM

Thermodynamics

(a)
Free Time → Kinetics

Free Money → economic wise

Free Energy → means from where?

(b) Spontaneous → process proceeds without needing energy

temperature

winter $-20°C$
summer $+35°C$
→ if spontaneous @ $10°C$

wrong mix — can also be our "air"

(c) temperature

°K - Kelvin temperature 273.15°K - yes

°C - Celsuis temperature 0° C - yes

°F - Fahrenheit 32°F - no.

⇓

to thermodynamics calculations

Thermodynamics - names etc.

November 18, 2024 11:07 AM

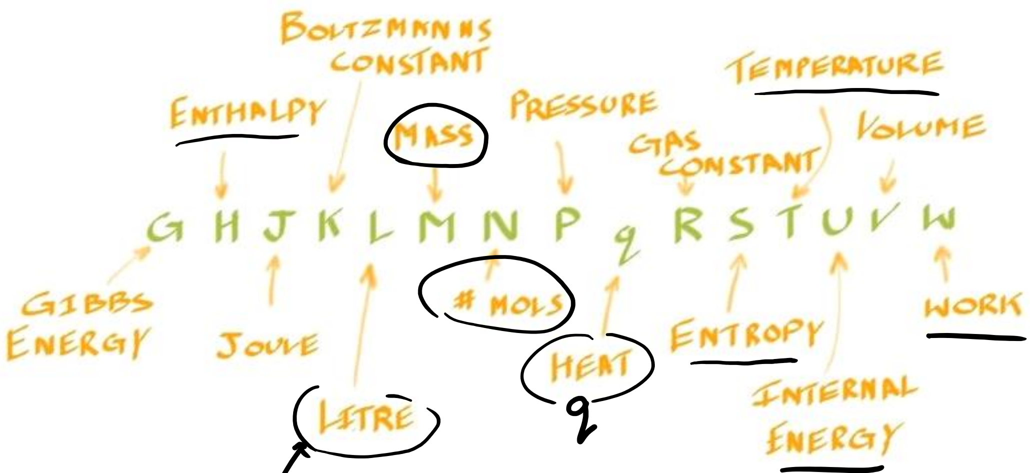
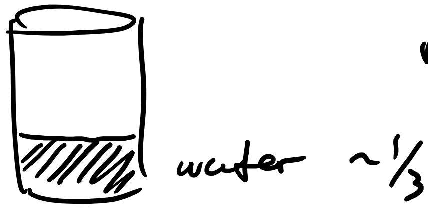


Figure 1. The thermodynamic alphabet.

measure - metric unit of volume - dm^3 - cubic decimeter

cm^3 - centmeters

m^3 - metres



Thermodynamics

November 20, 2024 7:52 AM

why do
some things
happen on their own?
mechanical? or
a chemical process?

APS110H1f2024 November 22, 2024

November 22, 2024 8:28 AM

Thermodynamics

energy

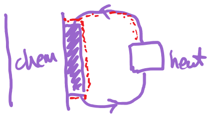
exothermic
- released energy

which one?

endothermic
- "absorbs energy"
"- takes on energy"

which one process wise?

not APS110



something else

entropy (S)

heat transfer

$$\Delta S = \frac{q_{rev}}{T}$$

temp

"2nd Law of Thermodynamics"

"Entropy of Universe increase in any spontaneous process"

closer look at energy

internal energy

example example

$$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$$

$$= \frac{q_1}{T_1} + \frac{q_2}{T_2} \qquad \frac{\text{heat}}{\text{temperature}}$$

mechanical

↳ food bootle - break my table

chemical

↳ shipping of an 401(

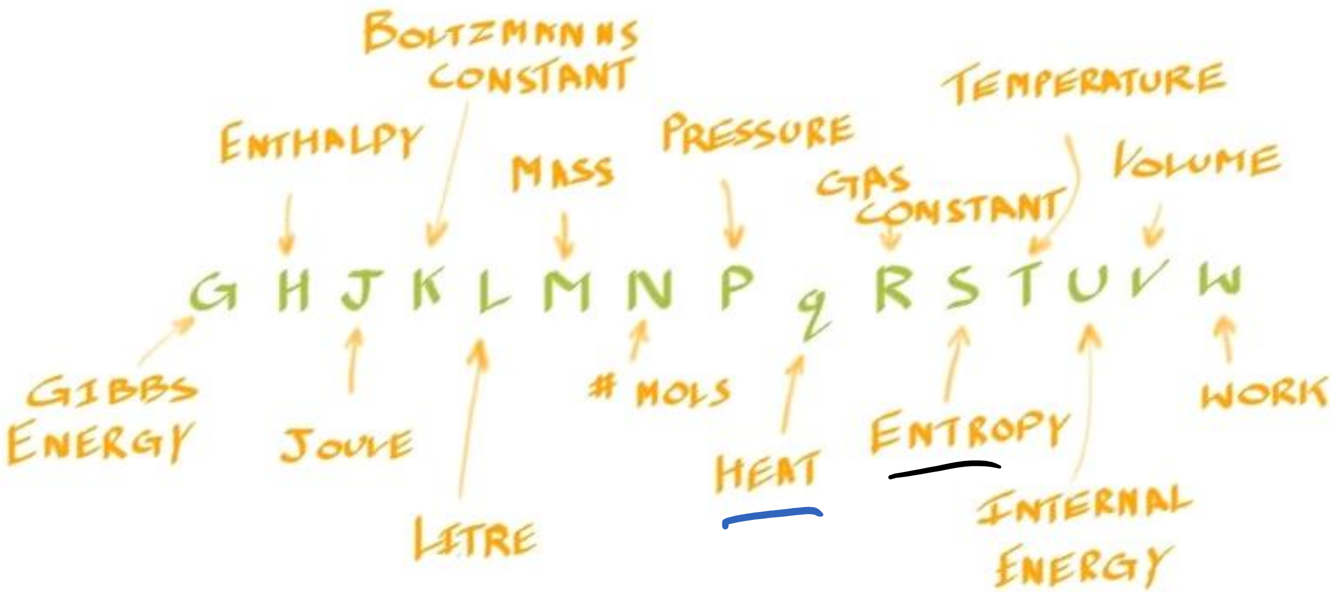


Figure 1. The thermodynamic alphabet.

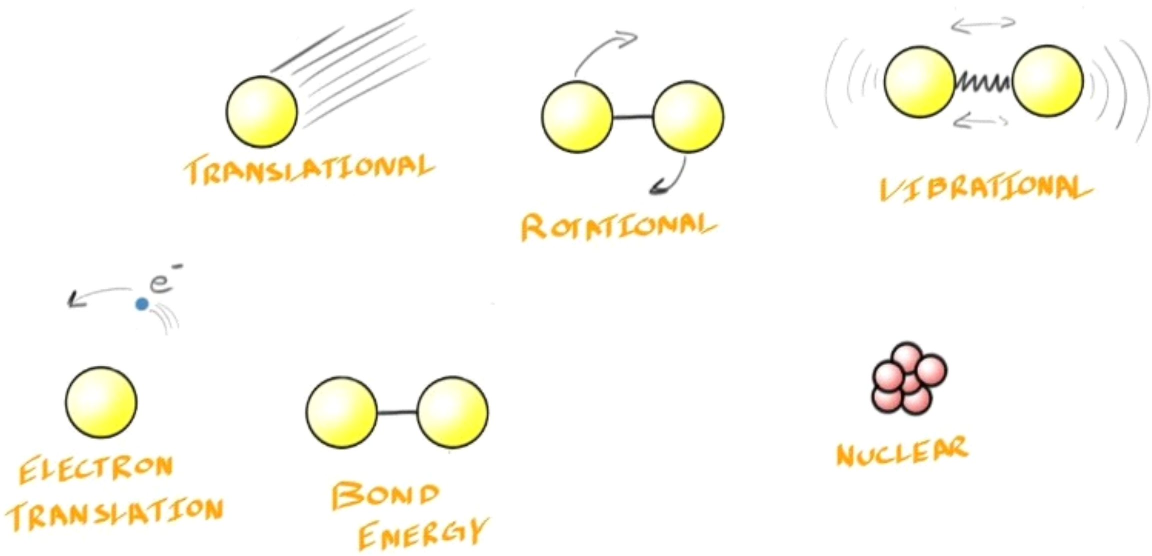


Figure 3. Some of the potential forms of energy contributing to the internal energy. Don't let this intimidate you; we don't need to calculate each of these, and we don't really care especially about the specific nature of the internal energy. We only concern ourselves with changes to the internal energy.

Thermodynamics

internal energy U

"1st Law of thermodynamics"

Isolated system

$\Delta U = 0$

" U - internal energy"

Closed system

$\Delta U = q + w$

"heat in" "work out"

a special subset of process:

constant pressure

only expanison of work (w)

$\Delta H = \Delta U + P\Delta V$

enthalpy

internal energy

pressure

volume

another subset

constant temperature + pressure

"Gibbs Free Energy" G

$\Delta G = \Delta H - T\Delta S$

enthalpy

temperature

entropy

(phase equilibrium/ equilibria)

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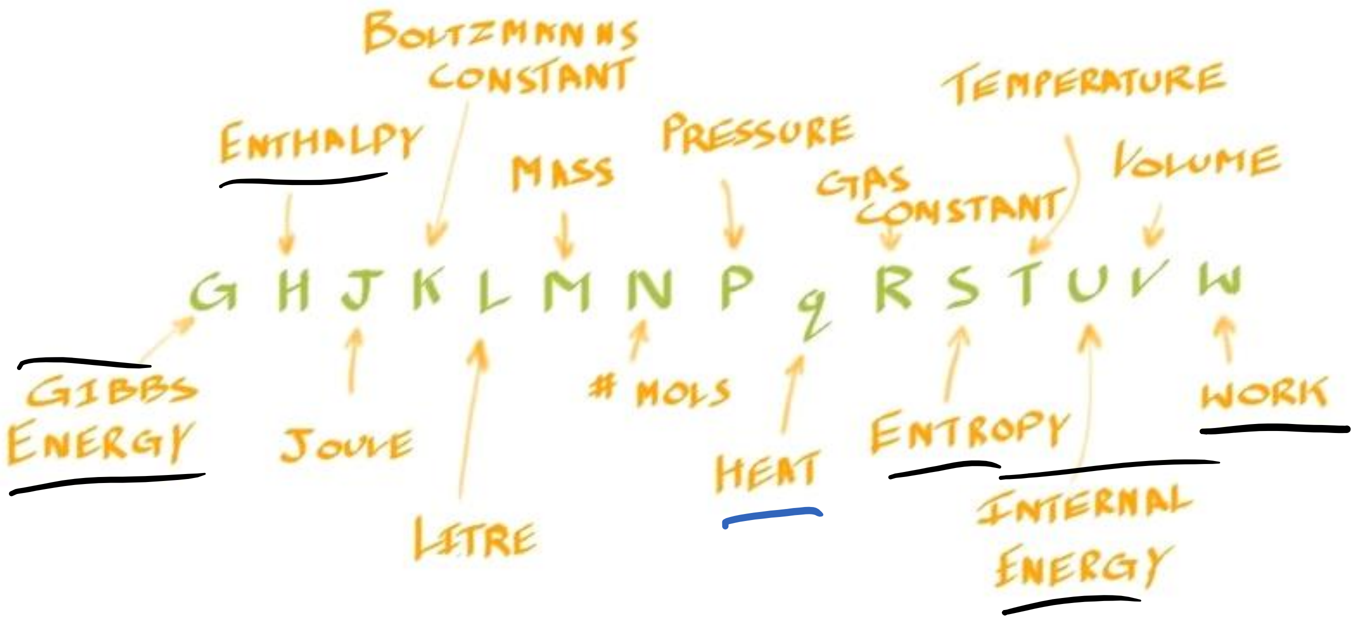


Figure 1. The thermodynamic alphabet.

November 20, 2024 8:18 AM

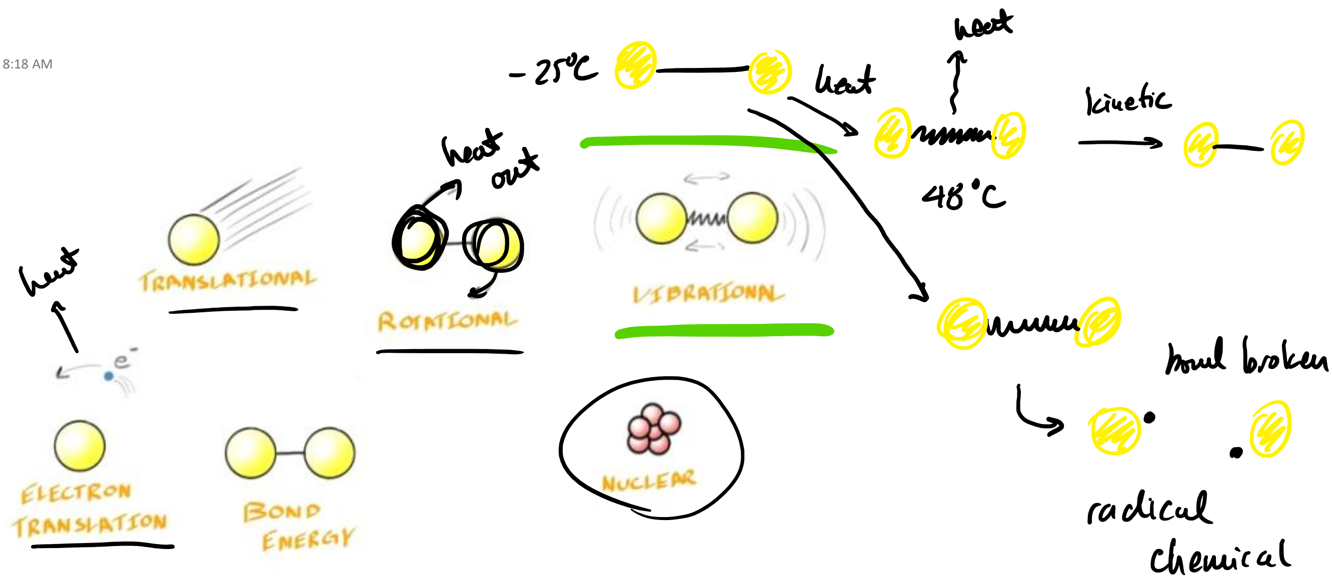
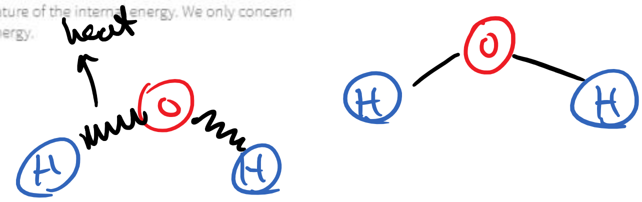


Figure 3. Some of the potential forms of energy contributing to the internal energy. Don't let this intimidate you; we don't need to calculate each of these, and we don't really care especially about the specific nature of the internal energy. We only concern ourselves with changes to the internal energy.



Note: 53 C shall be/should have been at the midpoint of 0-100 C - but was just to outline the difference of different chemicals - Figure 5 is of water...

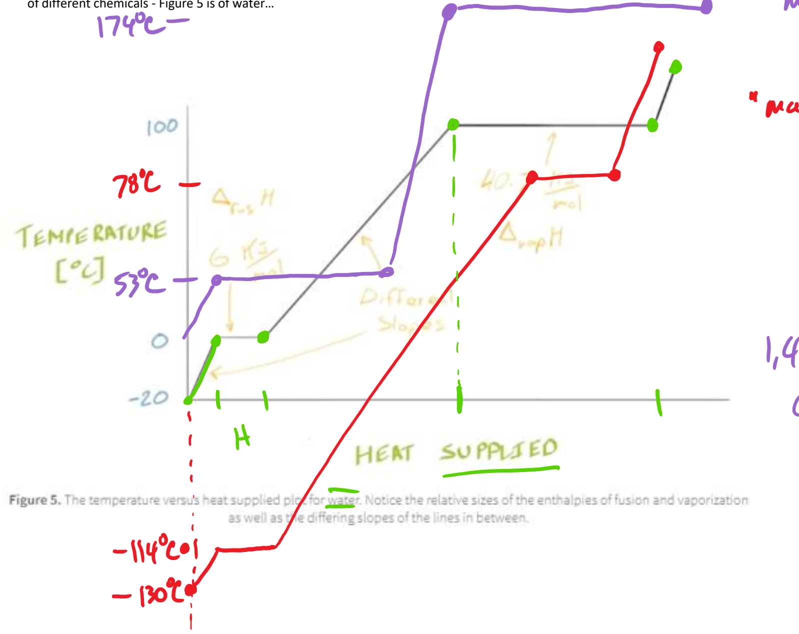
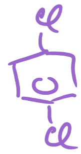


Figure 5. The temperature versus heat supplied plot for water. Notice the relative sizes of the enthalpies of fusion and vaporization as well as the differing slopes of the lines in between.



1,4-dichlorobenzene
chemical solvent

$$\text{slope} = \frac{\Delta T}{q} \quad \frac{\text{temperature}}{\text{heat}}$$

$$q = \frac{1}{\text{slope}} \Delta T$$

$$q = n\, C_p\, \Delta T$$

temperature

#mol

molar heat capacity - constant pressure

$$q = m\, c\, \Delta T$$

temp.

mass

specific heat

November 25, 2024 9:36 AM

Thermodynamics

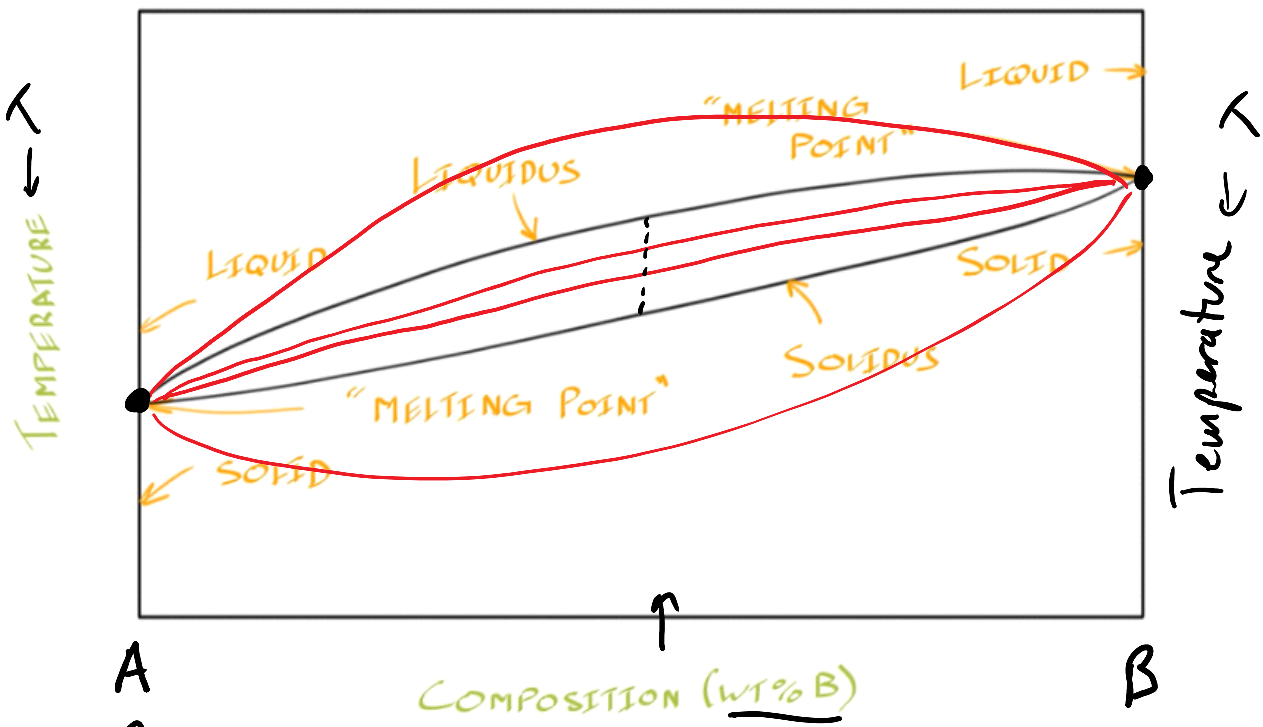


Figure 5: A schematic binary isomorphous phase diagram for the hypothetical two-component A-B system, showing the liquidus and solidus.

100%

50:50
A : B

100%

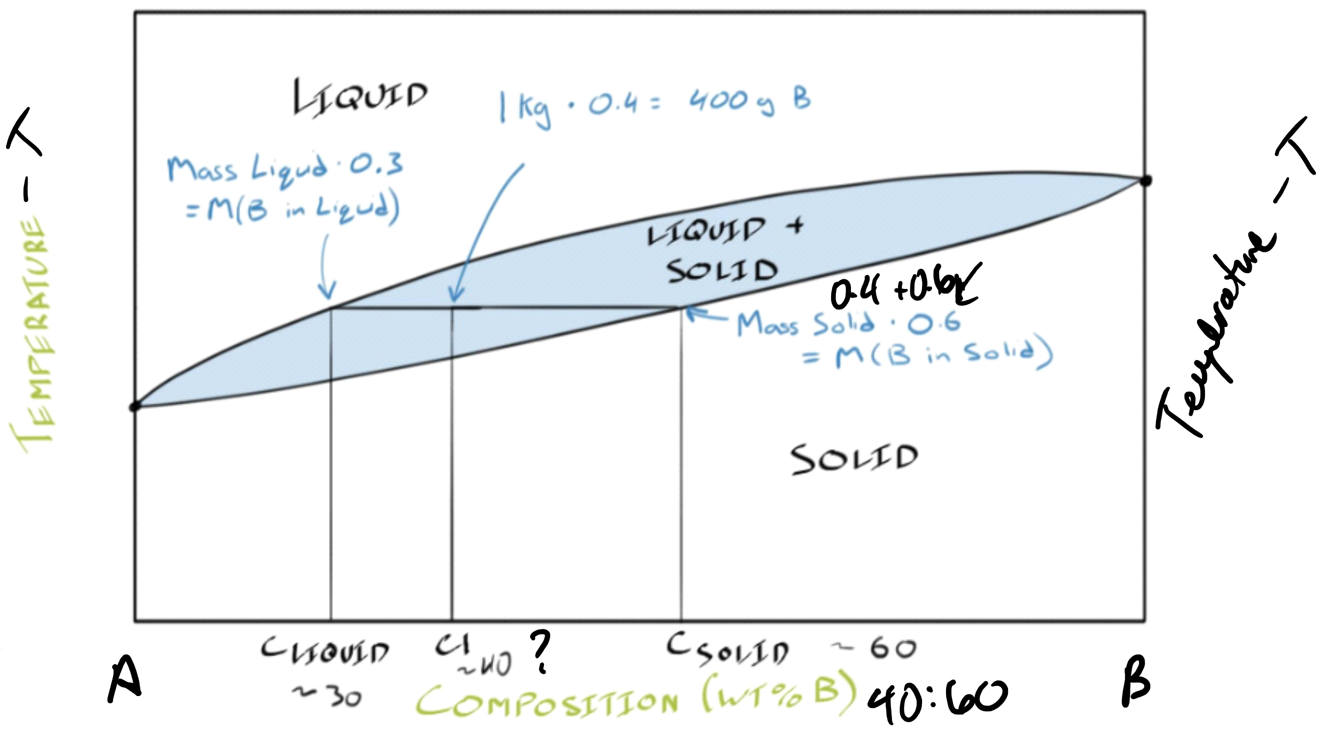
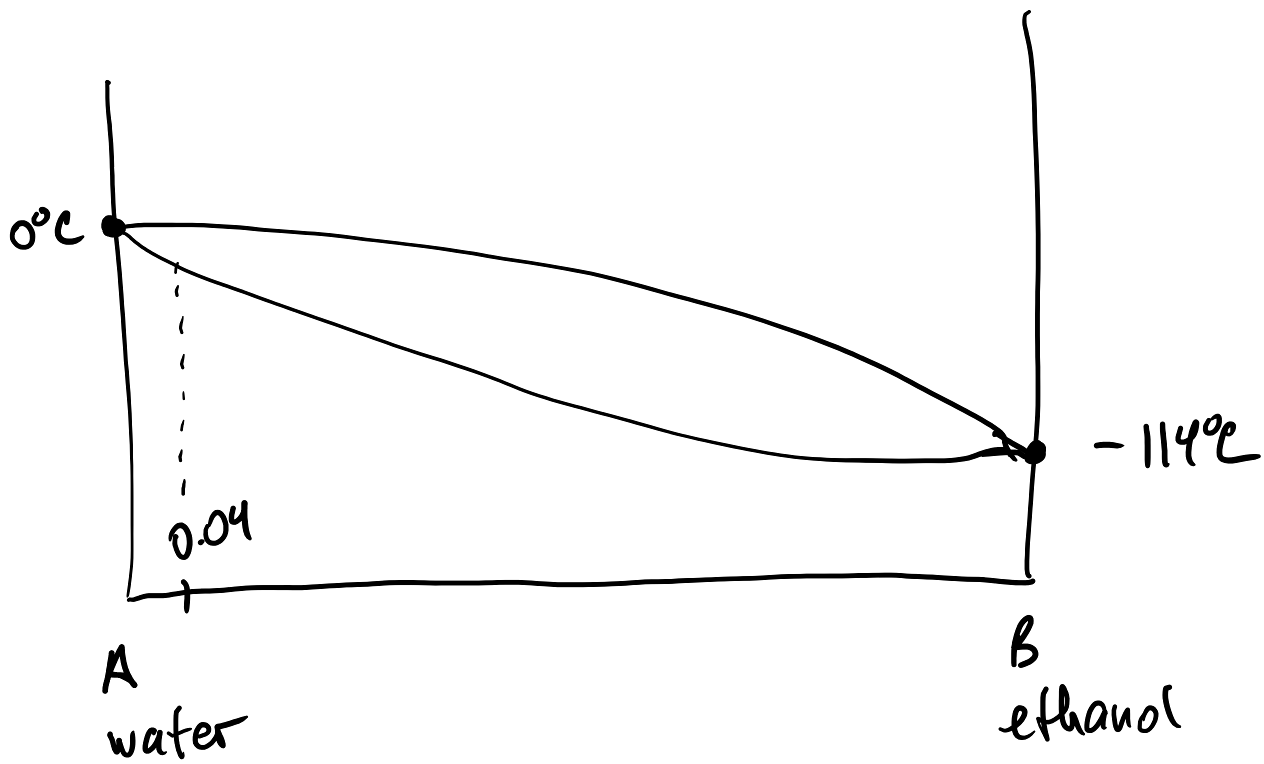


Figure 11: A 1 kg sample having a composition of 40 wt% B contains 400 grams of component B, separated into a mass of B in the liquid, M(B in Liq) and a mass of B in the solid, M(B in Solid).



Electrochemistry

November 26, 2024 4:51 PM

Section 13: ?Q

R ? Q: Yes on my notes it was Section 12: "...this chapter is terrible" - so yes it is Section 12
And for Section 13: "I'm so funny... to discuss a few things... before we can drive into electrochemistry"
... so sorry I was thinking of that note I had on hand to be related to electrochemistry - but here is the true comments of Section 12 and Section 13....

Splitting up oxidation and reduction

The aluminothermic reduction of iron reaction (Reaction 10) is a nice stepping stone to transition into the business that this chapter is supposed to be about: electrochemistry! You see, as the name implies, iron is being *reduced*. This means that iron is gaining electrons (perhaps you've heard that LEO the lion says, "GER," reminding us that we **L**ose **E**lectrons in **O**xidation and **G**ain **E**lectrons in **R**eduction). We can write out just the most simple thing that is happening to iron in the reaction

$$\underset{2\times 3^{+}\quad 6^{-}}{Fe_2O_3} + 2\,Al^{0} \longrightarrow \underset{2\times 3^{+}}{Al_2O_3} + Fe^{0}$$

is thermodynamic!

$$Al^{0} \longrightarrow Al^{3+} + 3e^{-} \qquad \text{"oxidation"}$$

$[Ne]\,3s^2\,3p^1$

$= 1s^2\,2s^2\,2p^6\,3s^2\,3p^1$

"metal"

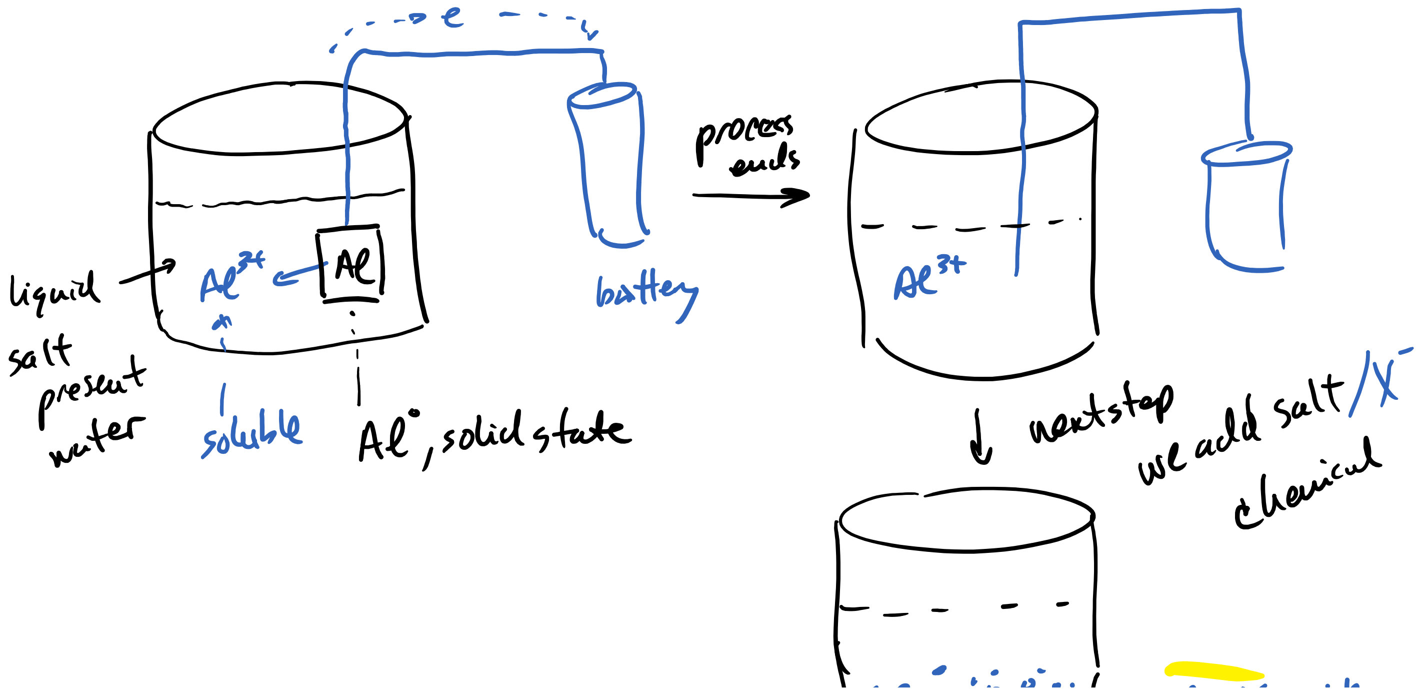
$$Fe^{3+} \xrightarrow{+3e^{-}} Fe^{0} \qquad \text{"reduction"}$$

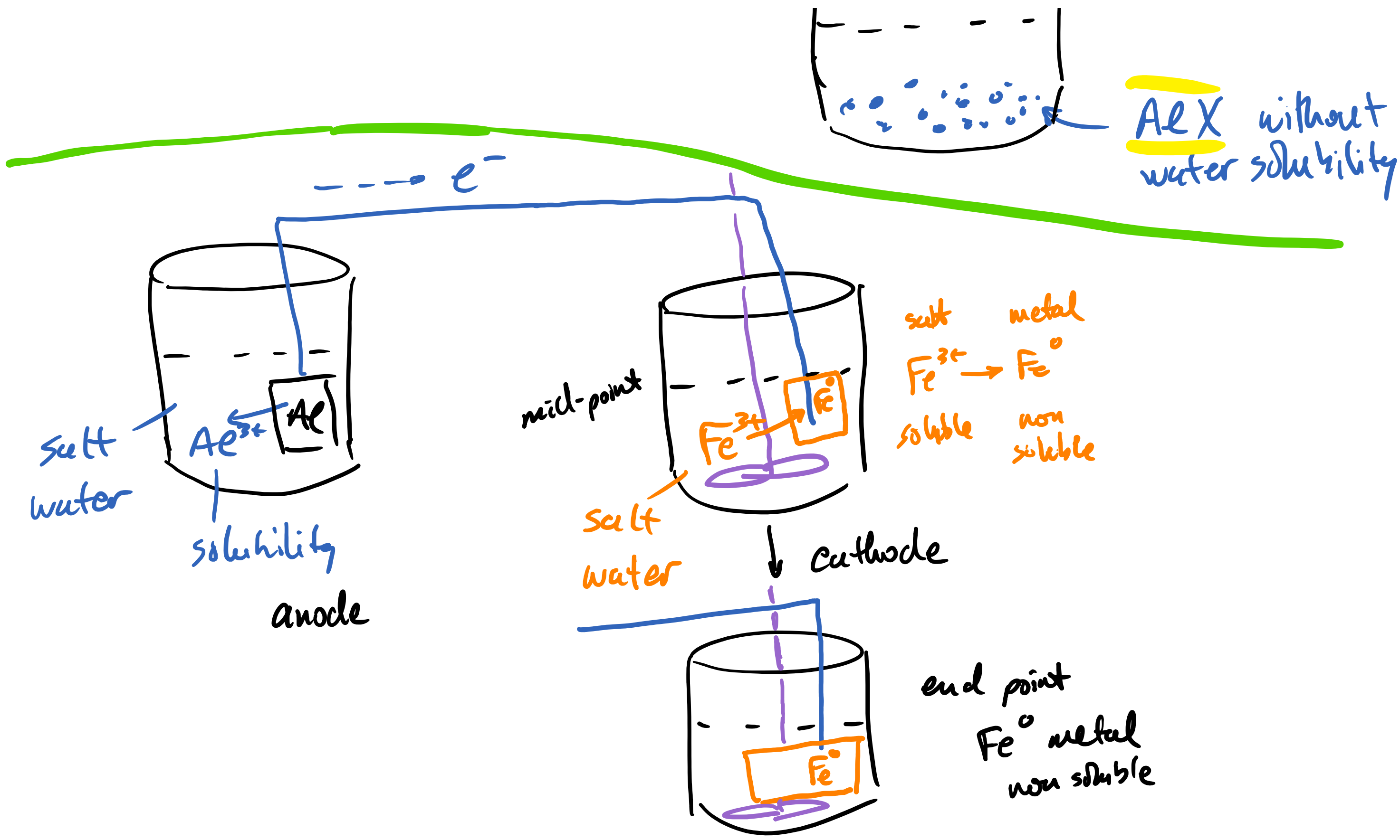
"salt"

$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^6$

Electrochemistry

Electrochemistry unit design and outcomes...




AlX without water solubility
e⁻
salt water
Al³⁺
Al
solubility
anode
mid-point
Fe³⁺
Fe°
salt metal
Fe³⁺ → Fe°
soluble non soluble
salt water
cathode
end point
Fe° metal
non soluble

Re: slide 11 from November 25: https://www.svpscentre.utoronto.ca/2024/11/12/december-6-2024/

Electrochemistry → Mineral Process

$\overset{2+}{Zn}\overset{2+}{Fe}S_2^{(2+2^-)}$

zinc - iron - sulfur

mass balance ⇒ $4\,ZnFeS_2 + 19\,O_2 + 4\,H_2O$ (oxygen, water)

how to mix?
require heat?

$$\downarrow$$

$4\,Zn^{2+} + 2\,Fe_2O_3 + 8\,H_2SO_4$

iron oxo   sulfuric acid

HO–S(=O)(=O)–OH

$S^{2-} \rightarrow S^{2+} \rightarrow S^{4+} \rightarrow S^{6+}$

$S^0\ 1s^2 2s^2 2p^6 3s^2 3p^4$

water add

solubility – $4\,Zn^{2+} + 8\,H_2SO_4$ "separated" $2\,Fe_2O_3$ – low solubility

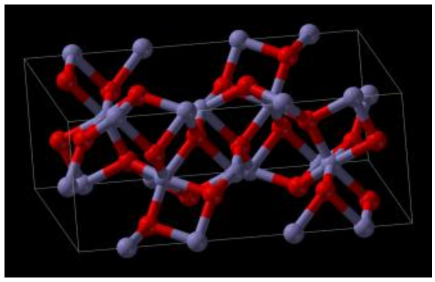
electrochemistry 0.763V   water still present.

$4\,Zn^0 + 8\,H_2SO_4$

electro chemistry   maybe solubilize it?

$2\,Fe^0 + 3O_2$

solid



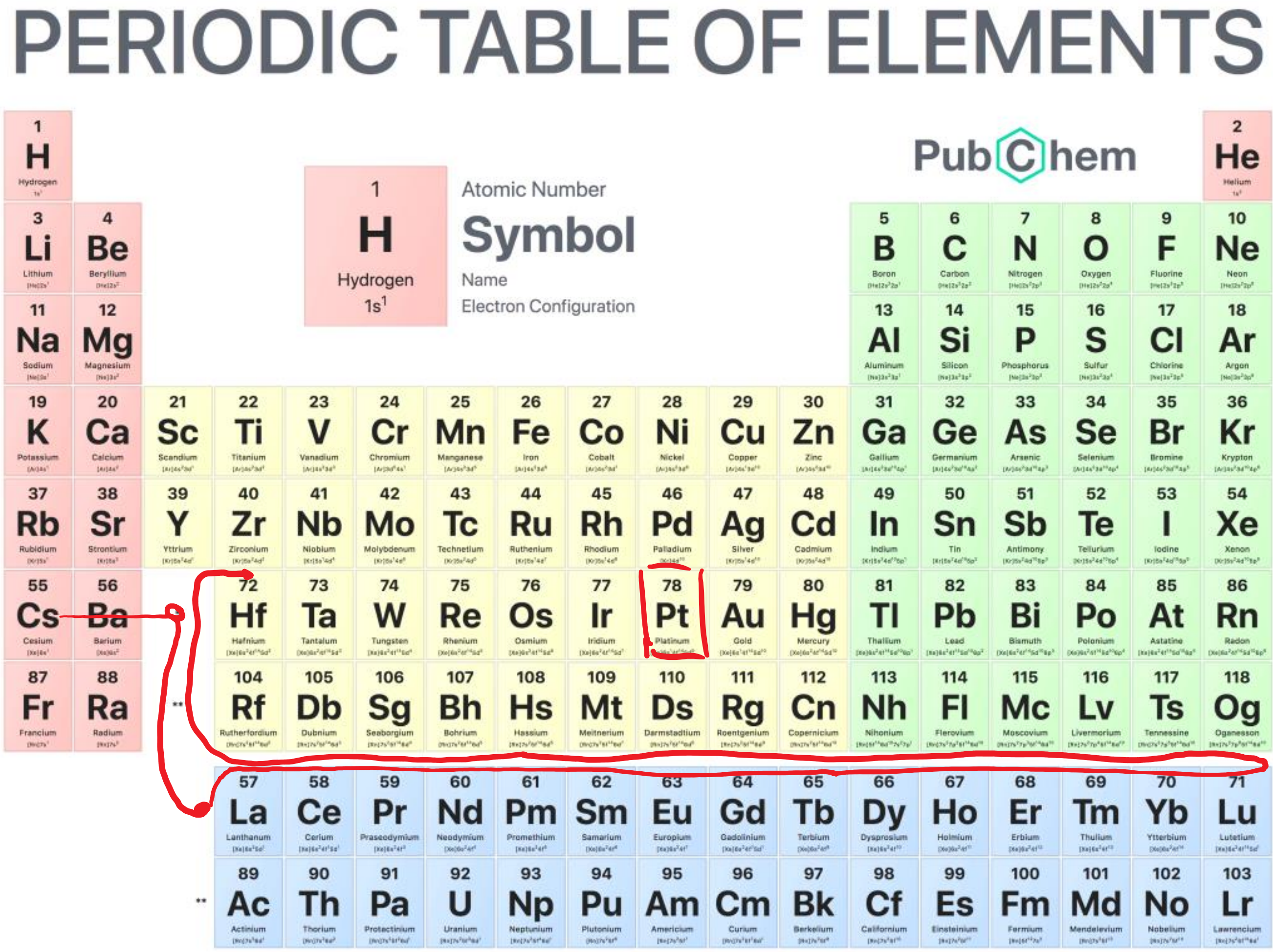
3D

November 29, 2024 2:42 PM

Reduction Reaction	E° (V)
$Li^{+}_{(aq)} + e^{-} \rightarrow Li_{(s)}$	- 3.045
$Zn^{2+}_{(aq)} + 2e^{-} \rightarrow Zn_{(s)}$	- 0.763
$Fe^{2+}_{(aq)} + 2e^{-} \rightarrow Fe_{(s)}$	- 0.44
$2H^{+}_{(aq)} + 2e^{-} \rightarrow H_{2(g)}$	0.000
$Cu^{2+}_{(aq)} + 2e^{-} \rightarrow Cu_{(s)}$ copper	+ 0.337
$Pt^{2+}_{(aq)} + 2e^{-} \rightarrow Pt_{(s)}$ platium	+ 1.2

Table 1. Standard reduction potentials for a few half-cell reactions.

November 29, 2024 2:44 PM



APS110H1f2024 December 2, 2024

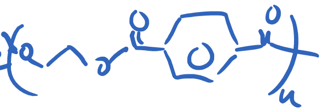
December 2, 2024 8:05 AM

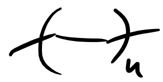
Re-Introduction

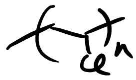
Metals → Cu^0, Fe^0, Al^0 etc.

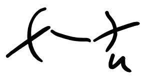
Ceramics → Al_2O_3, SiO_2, CuO "non-salts"

"salts" → $NaCl$, LiF, CaF_2 etc

Polymers → (1) poly ethylenetetraphthalate  not APS110.

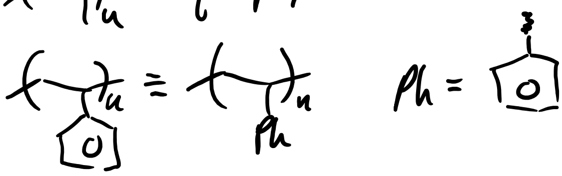
(2) low density poly(ethylene) 

(3) poly(vinyl chloride) 

(4) high density poly(ethylene) 

n - length of a polymer

(5) poly(propylene) 

(6) poly(styrene) 

Chemicals

Re-Introduction

December 2, 2024 10:26 AM

metal

polymer/rubber

polymer or metal

"clear"

polymer

metal

colour.

calcium + silicon + oxygen

concrete

glass

SiO_2

metal

ceramic

polymer

= maybe all of them

mineral engineering

chemical engineering

$\Rightarrow$ materials engineering

mechanical engineering

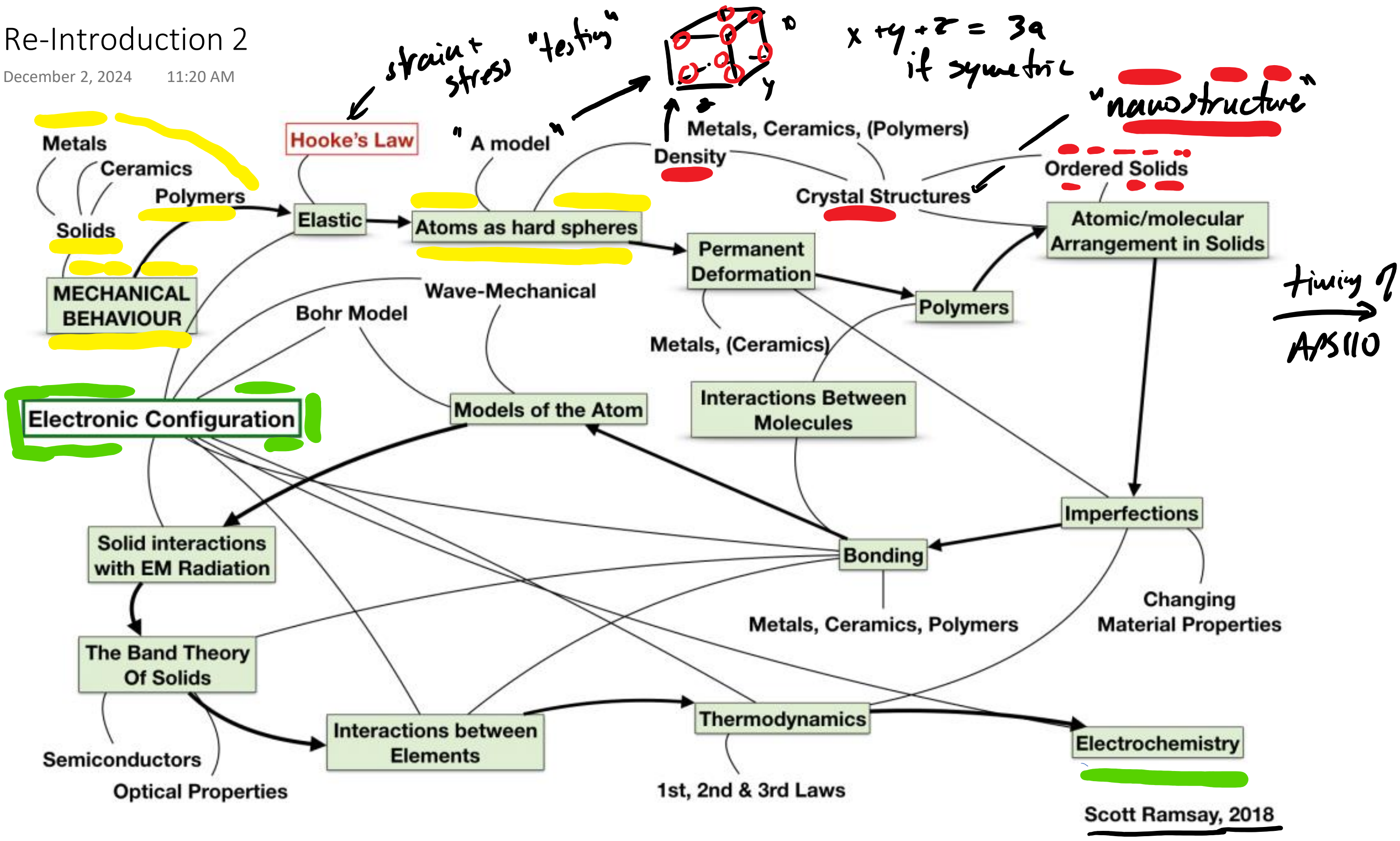
electrical engineering

computer engineering

civil engineering

Re-Introduction 2

December 2, 2024 11:20 AM



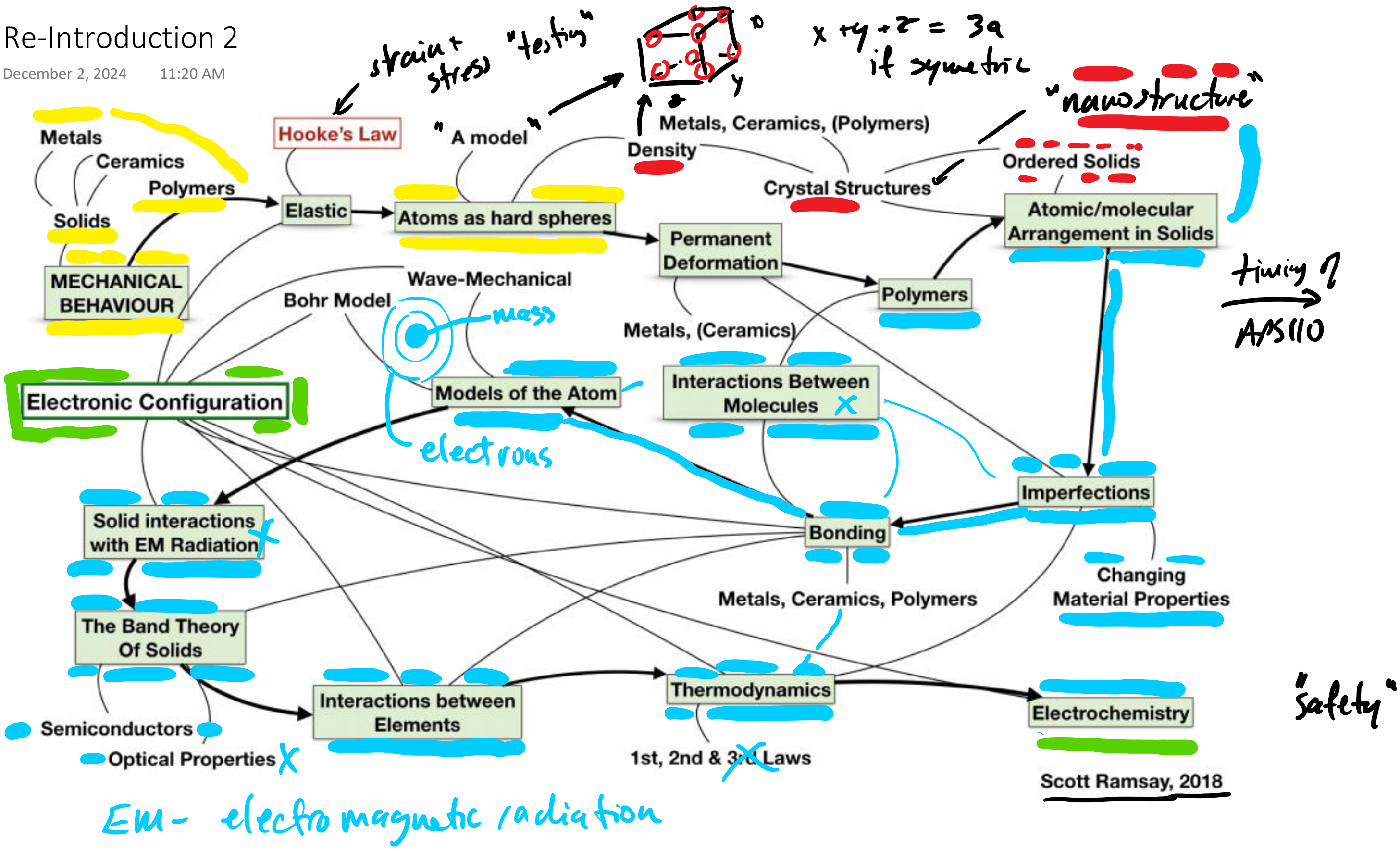
APS110H1f2024 December 4, 2024

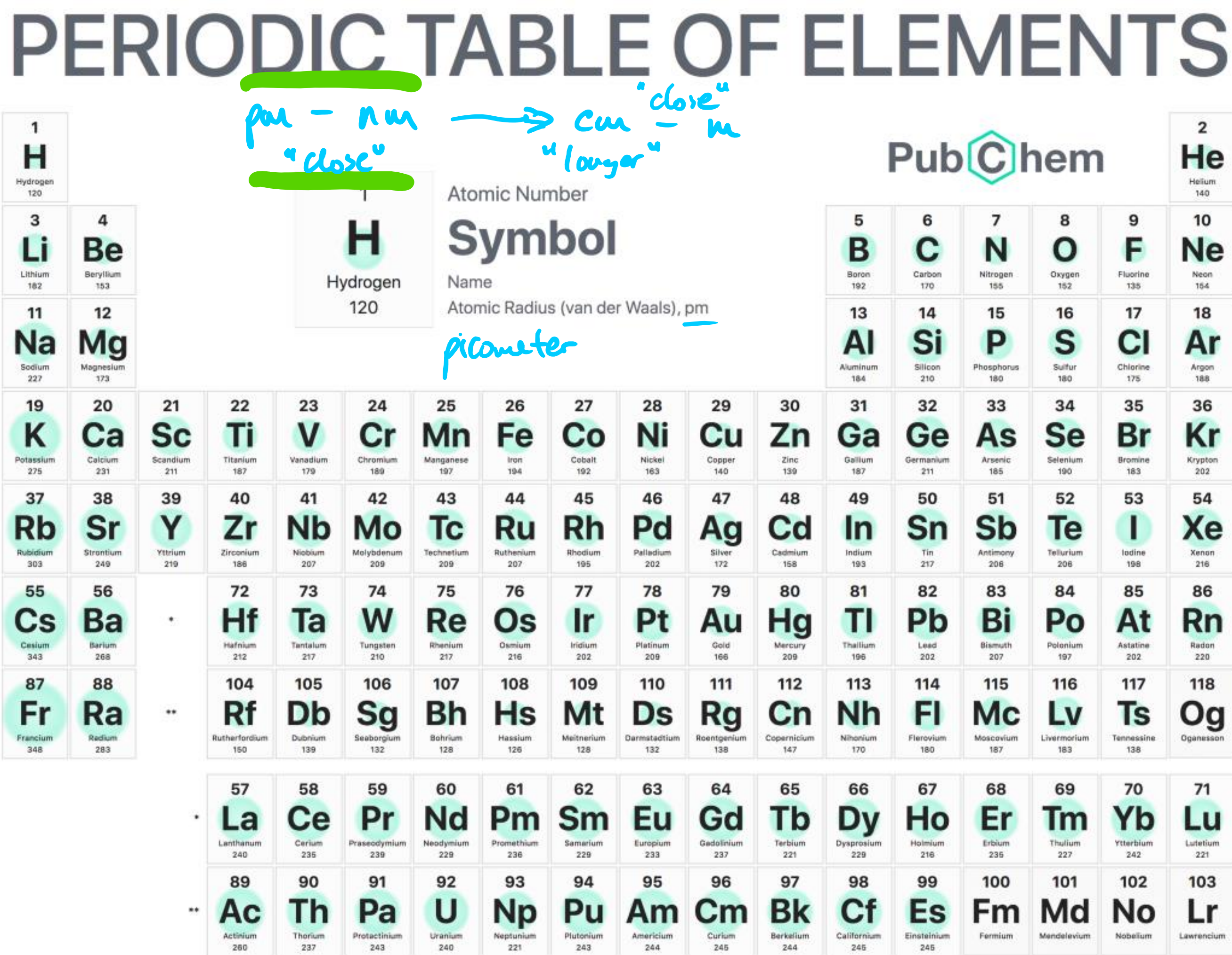
December 4, 2024 8:13 AM

Re-introduction: → next page

Re-Introduction 2

December 2, 2024 11:20 AM




PERIODIC TABLE OF ELEMENTS
pm – nm
"close"
→ cm – m
"close"
"longer"
PubChem
1
H
Hydrogen
120
Atomic Number
Symbol
Name
Atomic Radius (van der Waals), pm
picometer

PERIODIC TABLE OF ELEMENTS