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H. Chem. per. 7
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Nuclear Chemistry Study Guide (Chapters 4 & 25)

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(subtitles aren't included)

Shared Study Guide Discussion

There was unanimous agreement the Chem. chat of people wanting to make me share this study guide, so I'll use this introduction to share my thoughts on why I was **reluctant t**o share:

Pros:
- quicker completion
- more thorough completion
- missing information filled in
- errors corrected

Cons:
- errors that are made are more easily accepted as true
- if you didn't contribute to a certain part of a study guide (and if you rely only on the study guide), then the study guide may not help you at all with that section (I find that *reading* over information is much less effective than *writing* or typing or doing it again)

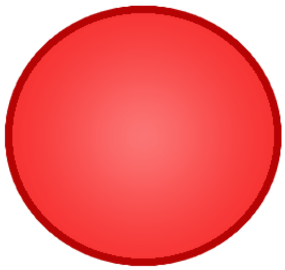
But I felt that, especially for large tests such as the Chem. ones that people don't tend to do so well on, the positives would outweigh the negatives. So I made this, and made it all fancy, even with this introduction on my rambling thoughts.

So feel free to openly contribute (there's a lot of content!), share to responsible people, and use it to *help* you study — but make sure to study with other methods as well. It sounded like in the Chem. chat that you might be desperate for this to study, but don't be — prepare in other ways. I've had people use my study guides in the past and blame me for not including all the information (Mahad!) that I might have thought was irrelevant and not included.

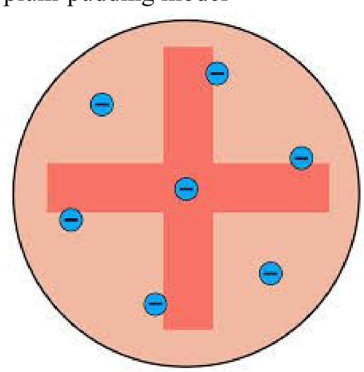
And lastly, because of the length of these study guides, make sure not to print in color and to print two-sided. I hope this helps like you all said it would!

Concepts

- **Atomic Development (Chapter 4.1)**
    a. Democritus (ancient Greece)
        - matter made up of tiny indivisible particles (atomos)
    b. Aristotle (also Greek)
        - thought Democritus' theory was wrong, and people listened
    c. Alchemists
        - mix of science and mysticism
        - no truly controlled experiments
    d. Dalton (early 1800s Britain)
        - billiard-ball model



        - atoms were uniform, solid sphere
        - four postulates
        - He was a school teacher
            - elements composed of tiny *indivisible* particles called atoms
                - now we know of subatomic particles
            - atoms of same element are *identical*; atoms of different elements are different
                - now we know of isotopes (differing in mass and composition but same because of number of protons and chemical properties)
            - atoms of different elements combine in simple proportions to create compounds
            - in a *chemical reaction*, atoms are only rearranged, but not changed (or created or destroyed)
                - now we know of nuclear reactions and transmutation
    e. Crookes
        - discovered cathode rays that were deflected by electric fields and magnets
    f. Becquerel (not directly related to atomic theory)
        - discovered radioactivity, the spontaneous emission of radiation from nucleus
    g. (J. J.) Thomson
        - cathode ray tube experiments
        - discovered cathode rays were beams of negative particles called electrons
        - plum-pudding model

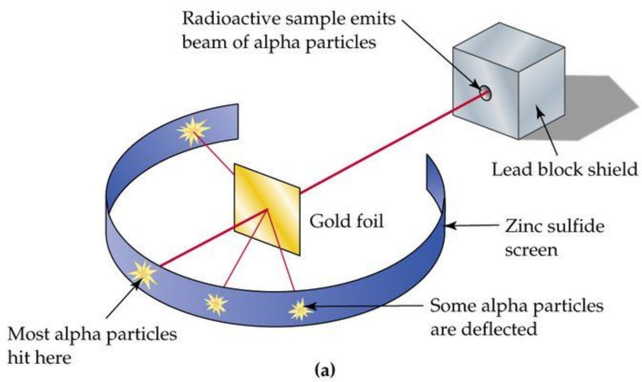


    h. Millikan
        - discovered charge and mass of electrons

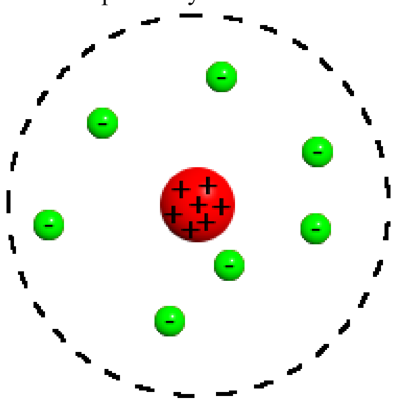
- used the oil drop experiments and the mass-to-electron charge calculated by Thomson

i. Rutherford

- discovered the nucleus, a positively charged, extremely dense center of an atom
- gold foil experiments

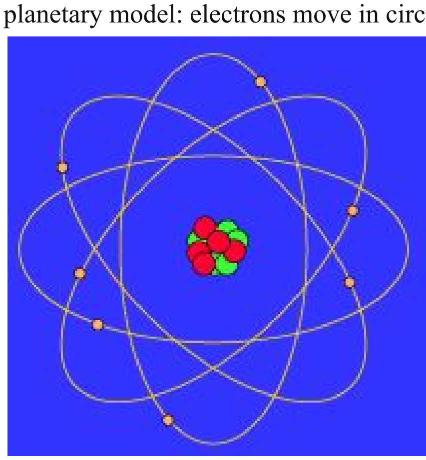


- discovered the protons as the positively charged particles in the nucleus
- nuclear / planetary model



j. Bohr

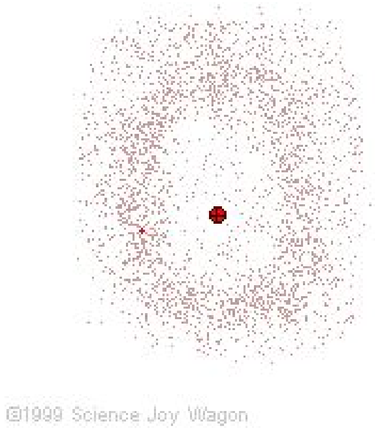
- used bright-line spectrum to try to explain presence of specific colors in hydrogen's spectrum
- discovered energy levels: electrons exist in specific energy states
- planetary model: electrons move in circular orbits in specific energy levels



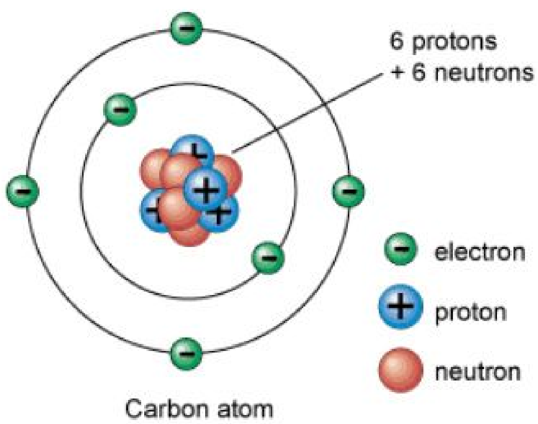
k. Schrodinger

- quantum mechanics: electrons only exist in specified energy states (like Bohr)

        - electron cloud model / wave model (current model)

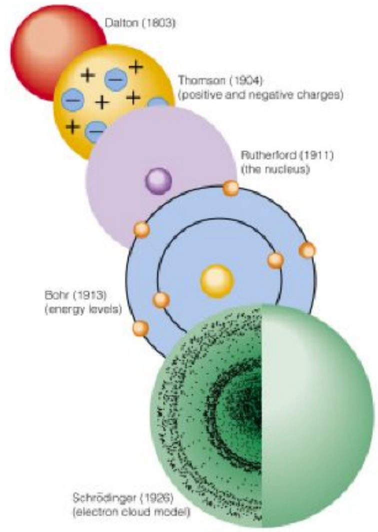


        - orbital: region around nucleus where electrons are likely to be found
            - no longer tell us where the electrons are going to be, but the area where they are found — quantum mechanics probability
    - Chadwick
        - discovered neutrons (worked with Rutherford and nuclear model)
        - used evidence from Joliot-Curie experiments
        - neutron model (revised Rutherford model)



    - Heisenberg
        - uncertainty principle: "the more precisely the position is determined, the less precisely the momentum is known in this instant, and vice versa"
        - quantum mechanical model

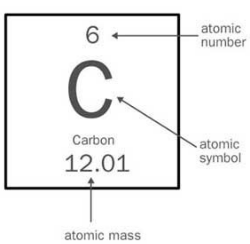
- Overall Evolution:



  - (models are used to show things that we cannot see or understand)

- **Subatomic Particles**
  - electron
    - Thomson with cathode ray experiments
    - e^-
    - negatively charged, tiny particles in the electron cloud / orbits
    - mass: ~1/1840 amu (0 in mass number)
    - charge: -1
  - proton
    - mass: ~ 1 amu
    - charge: +1
    - located in nucleus
  - neutron
    - mass roughly mass of proton + neutron (~ 1 amu)
    - charge: 0 (neutral)
    - located in nucleus

- **Atoms on the Periodic Table**



  -
  - (relative) atomic mass of an element is a weighted average of the element's isotopic atomic masses based on their relative abundances
    - relative abundance: percent abundance / 100%
    - percent abundance: (number of particles of that isotope) / (total particles of that element) x 100%
    - atomic mass of an isotope: same as mass number (electrons' masses are so low they are equated to 0 amu)
    - mass number: number of protons + neutrons of a certain isotope
  - atomic number: number of protons

        - for our purposes, also the number of electrons (neutral atoms)
    - atomic symbol:
        - one, two, or three (rare, at the end) unique letter symbols for an element. The first letter is capitalized, and the subsequent ones (if any) are lowercase

- **Isotopes**
    - forms of the same element differing only by the number of neutrons (and therefore the mass number and atomic mass)
    - have the same chemical (bonding) properties, but different isotopes may have different nuclear stabilities (some may be radioactive)
    - radioisotopes are radioactive isotopes
    - examples:
        - Hydrogen has three isotopes:
            - Hydrogen-1: protium, normal one
            - Hydrogen-2: deuterium, “heavy hydrogen”
            - Hydrogen-3: tritium, radioactive
            - All 3 isotopes of water are found in the water we drink
    - notations:
        - $${}^{\text{mass number}}_{\text{atomic number}}(\text{element symbol})^{\text{charge}}$$
            - A = mass number
            - Z = atomic number
            - charge is usually omitted
            - atomic number can be omitted because it is given by the element
        - [name]-[mass number]

- **Chemical vs. Nuclear Reactions**
    - chemical vs. nuclear reactions

Chemical	**Nuclear**
involve the electrons	involve the nucleus, and can involve electrons (all subatomic particles)
involve small energy changes	involve huge energy changes
rate can be affected by catalysts, temperature, surface area, concentration	reaction rate is only affected by concentration of reactants (e.g. in fission, you need a critical mass to begin spontaneous decay)
elements are not changed, atoms only rearranged	atoms can actually be changed from one element to another (transmutation)

- **Nuclear Equations**
    - a balanced equation that describes a nuclear reaction

- examples:

  a. $^{196}_{82}\text{Pb} + ^{0}_{-1}\text{e} \rightarrow ^{196}_{81}\text{Tl}$

  b. $^{28}_{15}\text{P} \rightarrow ^{0}_{+1}\beta + ^{28}_{14}\text{Si}$

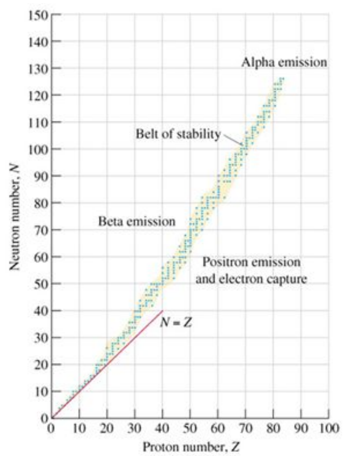
  c. $^{226}_{88}\text{Ra} \rightarrow ^{4}_{2}\alpha + ^{222}_{86}\text{Rn}$

  d. $^{73}_{30}\text{Zn} \rightarrow ^{0}_{-1}\beta + ^{73}_{31}\text{Ga}$
- instead of showing chemical representation of an element, the first isotopic notation ($^{A}_{Z}Sy$) is shown
  - for non-elements, the Z number (atomic number) is instead the charge, because a proton equates 1+ charge
- mass numbers and atomic numbers must be equal on both sides (shows conservation of mass, although there are minute mass→energy that we haven't really talked about)
- basic particles (not elements) and representations:
  - proton:
    - $^{1}_{1}H$
    - same as a protium nucleus
  - neutron:
    - $^{1}_{0}n$
    - often fired at other particles during induced transmutation
    - are shot off and cause other particles to fission in a spontaneous fission reaction
  - electron (beta particle):
    - β or $^{0}_{-1}e$
    - beta particles (positrons too) have penetrating power to go through top layers of skin; can be stopped with aluminum
    - emission used to increase atomic number (decrease n:p ratio) because neutrons turn into a proton and electron
    - capture used to increase n:p ratio and decrease atomic number
  - positron (also a beta particle):
    - β^{+} or $^{0}_{+1}e$
    - emission used to increase n:p ratio (similar to electron emission)
  - alpha particle
    - α or $^{4}_{2}He$
    - same as a helium-4 nucleus
    - least penetrating power: are big and slow particles; can be stopped by paper, clothing, or skin
    - usually happens with larger particles with high numbers of protons and neutrons: this decreases both of them
  - gamma ray
    - $^{0}_{0}\gamma$
    - pure energy
    - reactants and products don't show change
    - reactants may be marked with * to show energized electrons (that can give off gamma rays)
    - highest penetrating power, power to penetrate completely through our bodies and damage DNA; can be stopped by lead or concrete
    - major form of ionizing radiation

- **History of Radioactivity**
  - Roentgen discovered "invisible rays emitted when electrons bombarded the surface of certain materials" (X-rays)

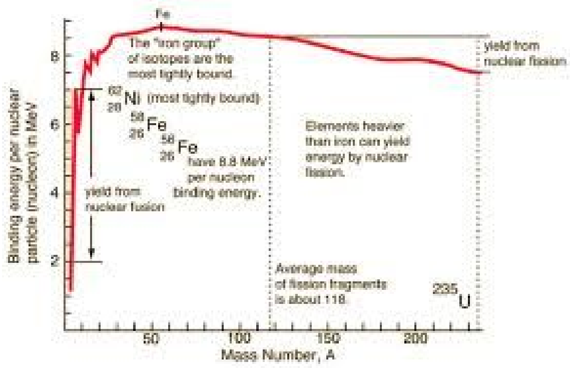
- caused photographic plates to darken
- Becquerel studied phosphorescence
  - noticed that radioactive elements (uranium) continued to darken photographic plates even when not exposed to light
- Marie and Pierre Curie worked with pitchblende (Becquerel's uranium sample) and isolated the uranium
  - also discovered radium and polonium
  - named radioactivity, and first unit of radioactivity named after her (Ci)
  - Marie Curie won the Nobel prize.

- **Radioactivity**
  - radioactivity
    - spontaneous emission of particles from nucleus to achieve stability
      - stability based on n:p ratio
    - also known as radioactive decay or nuclear decay. includes:
      - alpha emission
      - positron or electron (beta) emission
      - electron (beta) capture
      - gamma emission
      - fission
      - fusion
  - radiation
    - particles and energy given off with radioactivity
    - three types: alpha and beta particles, and gamma rays
  - radioactive particles (radioisotopes)
    - band of stability
      - elements near the n:p band of stability are stable



      - Just to explain: The elements to the right of the band of stability because there are too many protons; positron emission or electron capture lowers the number of protons and creates a more equal n:p ratio. Similarly, Beta emission occurs to the left of the band of stability because there are too many neutrons, and since beta heightens the number of protons, it helps even out the n:p. Alpha emission happens at the top because at that point the atom is just too big and since alpha emission releases and entire Helium nucleus this is used to make the atom more stable. -mk
    - binding energy per nucleon

- elements most stable around mass number 60 (iron): higher can undergo fission, and lower can undergo fusion

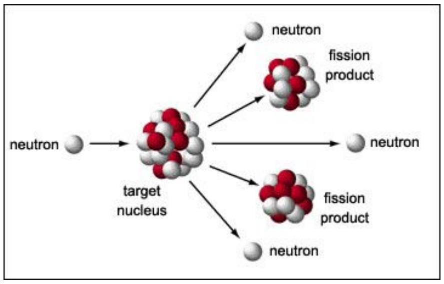


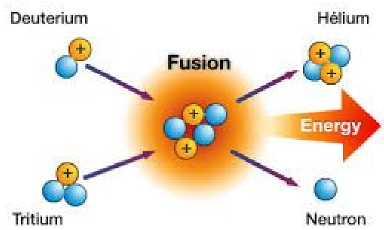
- half-life
  - similar to a sporting tournament
  - half is eliminated each time — not a linear function, but an exponential one because the variable is the exponent
  - $A = O \times 0.5^n$, $n = \frac{t}{T}$
  - length of half-life can vary from a few microseconds (maybe even smaller) to trillions of years (not very radioactive)
    - super-long half-lives show how it is possible for radioactive isotopes to still exist — they are still decaying from the longer ones
- Are the particles reactants or products?
  -

reactants:	products:
[particle] capture	[particle] emission
bombarded with [particle]	[particle] decay
emitted by [particle]	[particle] radiation
	loss of a [particle]

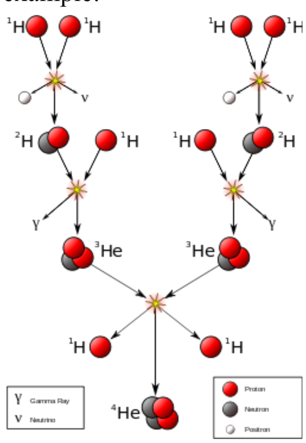
  -

- **Fission and Fusion**
  - fission:
    - when larger nuclei (mass # > 60 (Fe)) split up into smaller, more stable nuclei when hit by neutrons
    - if a *critical mass* is attained, then it can be a spontaneous reaction
      - subcritical: no spontaneous reaction
      - critical and supercritical: enough mass to start a reaction
    - it is spontaneous because the smaller particles (neutrons) fly off and hit other (unstable) nuclei, causing them to break; this happens over and over
    - Can cause changed reactions in which the reaction loses control which results in an explosion.

- 

- Fusion:
  - 

  - tokamak reactors use strong magnetic fields to control <u>fusion</u> reactions
  - require huge amounts of energy to start and sustain
    - nuclei repel each other, need to overcome this huge electrostatic repulsion
    - happens on stars (lots of pressure and heat)
  - mass is not conserved: tiny bits of of the matter in the nucleus is converted to energy
  - when smaller nuclei (mass # < 60 (Fe)) are joined together into larger, more stable nuclei
    - example:



- nuclear power
  - <u>breeder reactors</u> create fuel as a by product of the energy they produce
  - <u>control rods</u> control the nuclear reactions inside the core by absorbing neutrons that would otherwise hit fuel rods and initiate more chain reactions
- nuclear bombs

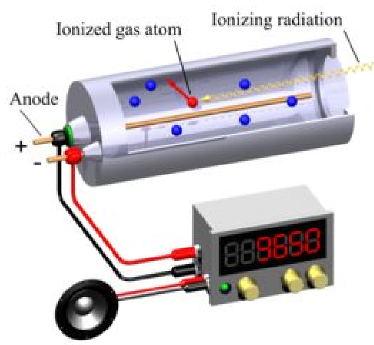
- **Nuclear Disasters and Sites**
-

	Site/Accident	**Environmental Concern**
Yucca Mountain	**Site/Nevada**	**Store Nuclear Waste from across the country (High Level)**
Hanford Nuclear Site	**Site/Washington State**	**Decommissioned in 1989**

	Made Pu for nuclear bombs	Waste entering River at present
Barnwell Nuclear Site (Energy Solutions)	**Site/South Carolina**	**Store Nuclear Waste from CT low-level Waste**
Millstone	**(site) Nuclear Power Plant in New England--CT**	**1 -1989 shut down other 2 are used today**
Three Mile Island	**Accident-Nuclear Power Plant Located in Pennsylvania**	**Leak 14 years to clean up Not a large concern to humans**
Chernobyl	**Accident-Ukraine 1996**	**Animal mutations from leaked radiation**
Fukushima	**Accident--Natural from earthquake in Japan Highest scale of accident**	**Widespread of radioactive contamination--across plants, soils, and animals Evacuation was across the board**
Windscale Fire	**Accident (1957) England**	**Radioactive isotopes were spread across England 500 Km milk was destroyed**
Kyshtym disaster	**Accident (1957) Russia 1st ever nuclear accident and was kept a secret until after Chernobyl**	**Radioactive cloud in Siberia Lake was contaminated School children were used in clean-up 1967--more contamination**
Hiroshima	**1945 WW11 Bomb--Little Boy**	**80 thousand died from bomb more died from radiation exposure**
Nagasaki	**1945 WW11--Fat Man**	**Radiation poison and debris plant mutations**
SL-1	**(Site)Experimental Nuclear power site for US Army 1961 Idaho**	**Never restarted after critical level reached**

- (Positive) Uses of Radioactivity
  - PET (positron emission tomography) scans
    - using radiotracers that undergo positron-emission to discover medical disorders
  - radiotracers
    - radioisotopes used to indicate the presence of an element in a sample
  - neutron activation analysis
    - a method to detect very small amounts of an element in a sample

- **Dangers of Radioactivity (to Human Health)**
  - ionizing radiation has the power to ionize atoms (make them ions), and therefore change bonding

        - especially important when it comes to DNA, because it can cause mutations, which can cause defects or cancer
            - somatic damage: when damage only affects the person, but not their offspring
            - genetic damage: when radiation can affect chromosomes and their offspring
    - detecting radiation
        - film badge
            - photographic film used to monitor radiation exposure
        - Geiger counter
            - 

            - uses ionizing power of ionizing radiation to create a negative charge that powers a counter
        - scintillation counter
            - scintillations are bright flashes of light when ionizing radiation excites electrons in certain types of atoms called phosphors
    - measuring radiation
        - radioactivity: decays per second
            - curie (Ci)
            - becquerel (Bq)
        - exposure: amount of radiation flying through air per second
            - roentgen (R)
        - absorbed dose: amount of radiation (energy) absorbed by a person
            - radiation absorbed dose (rad)
            - grey (Gy)
        - dose equivalent: amount of dose and medical effects of that type of radiation
            - roentgen equivalent man (rem)
                - people are usually exposed to 100-300mrem (0.1-0.3rem) a year

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Vocabulary

- cathode ray
    - a beam of electrons emitted from the cathode of a high-vacuum tube.
- atomic mass unit (amu)
    - unit of mass for atomic / molecular weights; equal to 1/12 of C-12 atom
    - protons and neutrons are ~ 1 amu
- transmutation
    - the turning of one element to another (number of protons changes)
    - (artificially) induced transmutation
        - when atoms are bombarded to cause transmutation
    - and yes, **we can turn things into gold now!** Now there's no more reason to practice medieval alchemy
- Radium Girls
    - the girls who worked in factories who made the glowing (radium watches)

- they often licked the point of the paintbrush (dipped in radium), ingesting lethal amounts of radium; sometimes they also smeared it on themselves to make them glow
- many of them had cancer early on and sued shortly before their deaths

- transuranium elements
  - all the elements after uranium on the periodic table
  - these were all created by induced transmutation and are all radioactive
- mass defect
  - tiny difference in mass between the nucleus and component nucleons. This is because some of the missing mass has been converted into the binding energy that holds the nucleus together (and because of $E = mc^2$, only a small amount of mass can produce the strong binding force)
- binding energy:
  - also known as the strong nuclear force
  - holds the nucleus together, despite the protons positive charge (repulsion)
  - strongest at around mass element 60
  - the weaker the binding energy, the more radioactive

Potential (Essential) Questions

Skills to Remember

- **Test-Taking Skills**
  - read all questions carefully
  - mark up what information you are given and what you are trying to find
  - DOUBLE / TRIPLE check if you have time **(lol you won`t tho)**
  - always attempt the bonus
  - do the rest of spirit week

- **Content-Relevant Skills**
  - calculating (relative) atomic mass
    - (R)AM = (RA * M) + (RA * M) + (RA * M)
      - (where RA = relative abundance (% abundance / 100) and M = mass of an isotope)
    - variations:
      - calculate mass, percent abundance, or relative abundance of an element given its atomic mass (and the other isotopes)
  - calculating half-life of a radioisotope
    - A = O x .5^n
      - where A = amount left (notice: not amount *decayed*), O = original amount (note: can be a percent or mass, depending on the question), and n = number of half-lives
    - n = t/T
      - where n = number of half-lives, t = total time, and T = length of half-life
    - variations:
      - calculate n, t, T, or O given all of the other variables
      - also know how to use log() function (to get exact numbers) or use inequalities for less exact numbers (in between two half-lives)
  - from past units:
    - SIG FIGS
      - measurements
      - operations
      - rounding

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            - heat and matter (probably not, but maybe we'll be tested on retention, maybe even as bonus/extra credit… who knows?)
                - $q = mCp\Delta T$
                - $q = m\Delta H$

- **Random Skills**
    - remembering everyone's hobbies from the beginning of the year
        - who knows? She warned this might come up as a bonus, and it hasn't yet… And if it comes up on a later test this is good review
    - watching the news
        - stay up to date for possible pop culture bonus (unlikely on a test rather than a quiz, but still possible)

Good luck on the test! Don't freak out and cram like we always do!

"Desire is the key to motivation, but it's determination and commitment to an unrelenting pursuit of your goal - a commitment to excellence - that will enable you to attain the success you seek."

"It's only cheating if you get caught"

~Mario Andretti

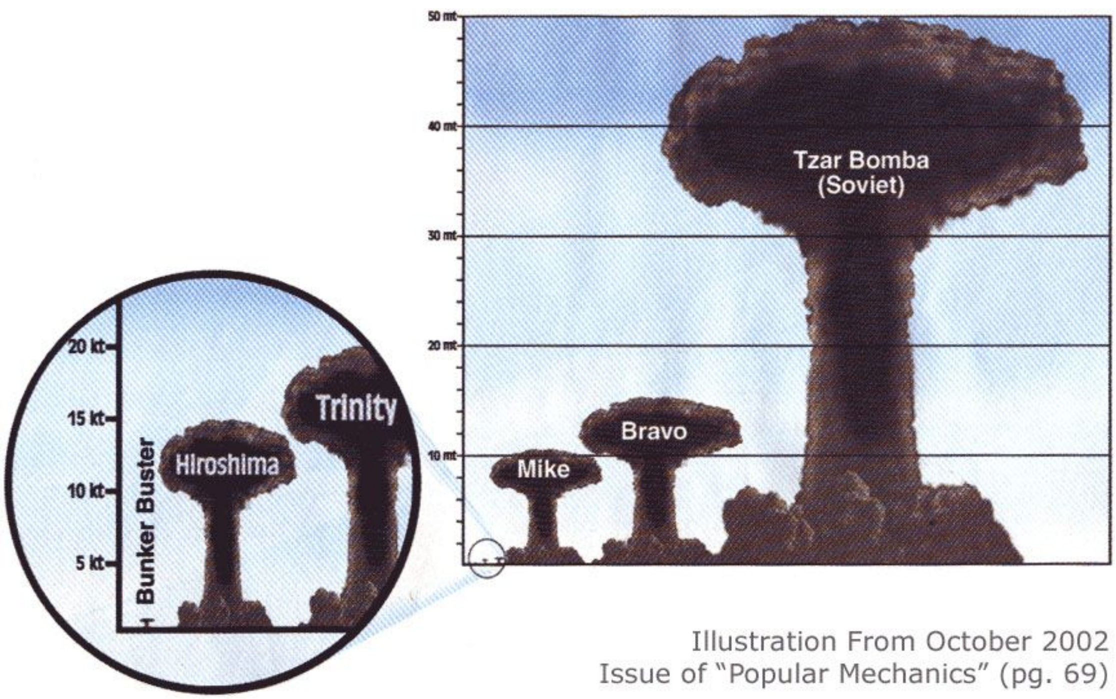

Illustration From October 2002
Issue of "Popular Mechanics" (pg. 69)

Pray that Soviet Russia will not nuke us…
Check out this website, very educational:
http://nuclearsecrecy.com/nukemap/