Name Answer Key 2013/2014 Hour

Unit 3 – The Nucleus

OBJECTIVES

1. I can identify the location, relative mass, and charge for electrons, protons, and neutrons.
2. I can recognize that protons repel each other and that a strong force needs to be present to keep the nucleus intact.
3. I can describe the atom as mostly empty space with an extremely small, dense nucleus consisting of the protons and neutrons and an electron cloud surrounding the nucleus, including the name of the person who made the discovery and a description of his experiment.
4. I can write the hyphen notation and nuclear symbol for an isotope.
5. I can recognize that all atoms of the same element always contain the same number of protons.
6. I can list the number of protons, neutrons, and electrons for any given ion or isotope.
7. I can calculate the average atomic mass of an element given the percent abundance and mass of the individual isotopes.
8. I can predict which isotope will have the greatest abundance given the possible isotopes for an element and the average atomic mass in the periodic table.
9. I can predict the outcome of a nuclear fission reaction.
10. I can explain the process of nuclear fusion.
11. I can explain the usefulness of fission reactions to humans.

VOCABULARY (I can define/describe the following terms in my own words)

- alpha particle
- atom
- atomic number
- average atomic mass
- beta particle
- electrons
- gamma ray
- half-life
- hyphen-notation
- isotope
- mass number
- neutrons
- nuclear symbol
- radioactive decay
- subatomic particles

Cloud Chamber Demo

DIRECTIONS: Watch the demonstration and record your observations under the following categories. Be specific and critical in your thinking.

I see...

I think...

I wonder...

Atomic Theory Article: The Early Days *by Anthony Carpi, Ph.D*

Until the final years of the nineteenth century, the accepted model of the atom resembled that of a billiard ball - a small, solid sphere. In 1897, J. J. Thomson dramatically changed the modern view of the atom with his discovery of the electron. Thomson's work suggested that the atom was not an "indivisible" particle as John Dalton had suggested but, a jigsaw puzzle made of smaller pieces.

Thomson's notion of the electron came from his work with a nineteenth century scientific curiosity: the cathode ray tube. For years scientists had known that if an electric current was passed through a vacuum tube, a stream of glowing material could be seen; however, no one could explain why. Thomson found that the mysterious glowing stream would bend toward a positively charged electric plate. Thomson theorized, and was later proven correct, that the stream was in fact made up of small particles, pieces of atoms that carried a negative charge. These particles were later named *electrons*.

After Eugen Goldstein's 1886 discovery that atoms had positive charges, Thomson imagined that atoms looked like pieces of raisin bread, a structure in which clumps of small, negatively charged electrons (the "raisins") were scattered inside a smear of positive charges. In 1908, Ernest Rutherford, a former student of Thomson's, proved Thomson's raisin bread structure incorrect.

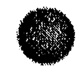
Rutherford performed a series of experiments with radioactive alpha particles. While it was unclear at the time what the alpha particle was, it was known to be very tiny. Rutherford fired tiny alpha particles at solid objects such as gold foil. He found that while most of the alpha particles passed right through the gold foil, a small number of alpha particles passed through at an angle (as if they had bumped up against something) and some bounced straight back like a tennis ball hitting a wall. Rutherford's experiments suggested that gold foil, and matter in general, had holes in it! These holes allowed most of the alpha particles to pass directly through, while a small number ricocheted off or bounced straight back because they hit a solid object.

In 1911, Rutherford proposed a revolutionary view of the atom. He suggested that the atom consisted of a small, dense core of positively charged particles in the center (or nucleus) of the atom, surrounded by a swirling ring of electrons. The nucleus was so dense that the alpha particles would bounce off of it, but the electrons were so tiny, and spread out at such great distances, that the alpha particles would pass right through this area of the atom. Rutherford's atom resembled a tiny solar system with the positively charged nucleus always at the center and the electrons revolving around the nucleus.

The positively charged particles in the nucleus of the atom were called protons. Protons carry an equal, but opposite, charge to electrons, but protons are much larger and heavier than electrons.

In 1932, James Chadwick discovered a third type of subatomic particle, which he named the neutron. Neutrons help stabilize the protons in the atom's nucleus. Because the nucleus is so tightly packed together, the positively charged protons would tend to repel each other normally. Neutrons help to reduce the repulsion between protons and stabilize the atom's nucleus. Neutrons always reside in the nucleus of atoms and they are about the same size as protons. However, neutrons do not have any electrical charge; they are electrically neutral.

Atoms are electrically neutral because the number of protons (+ charges) is equal to the number of electrons (- charges) and thus the two cancel out. As the atom gets larger, the number of protons increases, and so does the number of electrons (in the neutral state of the atom). The illustration linked below compares the two simplest atoms, hydrogen and helium.

Atoms are extremely small. One hydrogen atom (the smallest atom known) is approximately 5 x 10^{-8} mm in diameter. To put that in perspective, it would take almost 20 million hydrogen atoms to make a line as long as this dash -. Most of the space taken up by an atom is actually empty because the electron spins at a very far distance from the nucleus. For example, if we were to draw a hydrogen atom to scale and used a 1-cm proton (about the size of this picture - ), the atom's electron would spin at a distance of ~0.5 km from the nucleus. In other words, the atom would be larger than a football field!

Atoms of different elements are distinguished from each other by their number of protons (the number of protons is constant for all atoms of a single element; the number of neutrons and electrons can vary under some circumstances). To identify this important characteristic of atoms, the term *atomic number* (z) is used to describe the number of protons in an atom. For example, $z = 1$ for hydrogen and $z = 2$ for helium.

Another important characteristic of an atom is its weight, or atomic mass. The weight of an atom is roughly determined by the total number of protons and neutrons in the atom. While protons and neutrons are about the same size, the electron is more than 1,800 times smaller than the two. Thus the electrons' weight is inconsequential in determining the weight of an atom - it's like comparing the weight of a flea to the weight of an elephant.

Normally, atoms contain equal numbers of protons and electrons. Because the positive and negative charges cancel each other out, atoms are normally electrically neutral. But, while the number of protons is always constant in any atom of a given element, the number of electrons can vary.

Ions

When the number of electrons changes in an atom, the electrical charge changes. If an atom gains electrons, it picks up an imbalance of negatively charged particles and therefore becomes negative. If an atom loses electrons, the balance between positive and negative charges is shifted in the opposite direction and the atom becomes positive. In either case, the magnitude (+1, +2, -1, -2, etc.) of the electrical charge will correspond to the number of electrons gained or lost. Atoms that carry electrical charges are called ions (regardless of whether they are positive or negative). The electrical charge on the ion is always written as a superscript after the atom's symbol.

Isotopes

The number of neutrons in an atom can also vary. Two atoms of the same element that contain different numbers of neutrons are called isotopes. For example, normally hydrogen contains no neutrons. An isotope of hydrogen does exist that contains one neutron (commonly called deuterium). The atomic number (z) is the same in both isotopes; however the atomic mass increases by one in deuterium as the atom is made heavier by the extra neutron.

Parts of the Atom NOTES

Proton

- Positively charged subatomic particles
- Located IN the nucleus
- Equal in mass to neutron
- Much larger than electron

Neutron

- Neutrally charged subatomic particle
- Located IN the nucleus
- Equal in mass to proton
- Much larger than electron

Atom

Mostly empty space with a small, dense, positive center

Nucleus

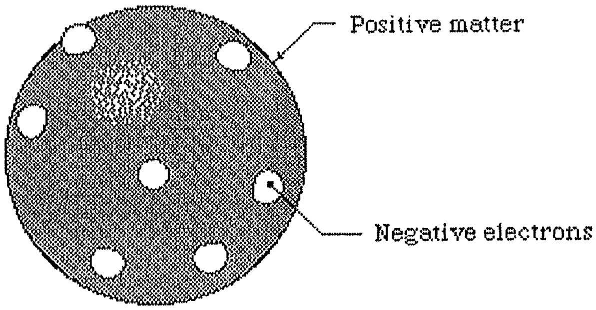
- Contains protons and neutrons
- Very dense at the center of the atom
- Contains essentially all of the mass
- Small in size compared to electron cloud.

Electron

- Negatively charged subatomic particle
- located OUTSIDE the nucleus
- Moving constantly
- Never know where it could be within its energy level
- Much much smaller than protons and neutrons

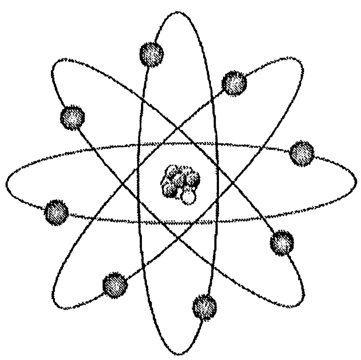
Historical Models of the Atom

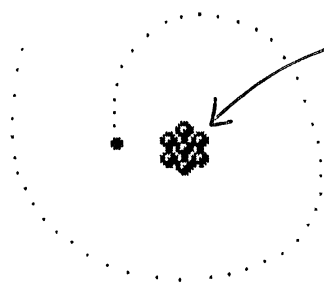
Plum Pudding



Discovered atom had multiple charges within.

Rutherford's model

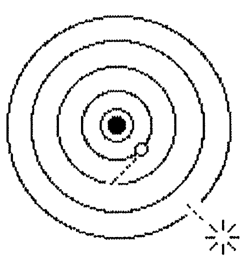


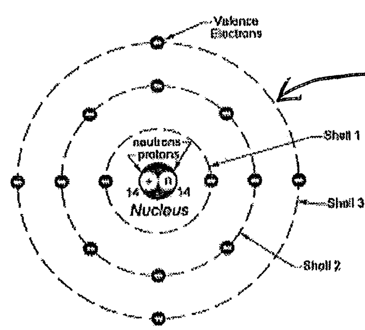


Nucleus

electrons do not fall into the nucleus.

Bohr Models

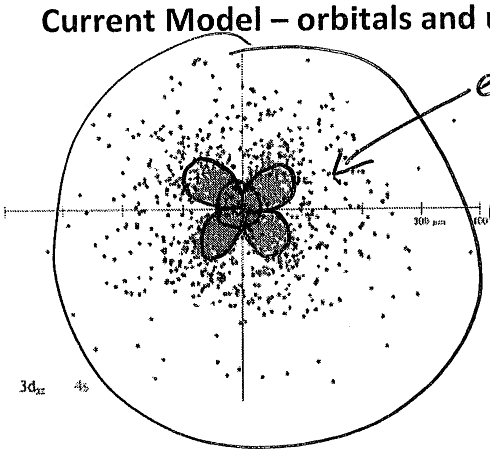




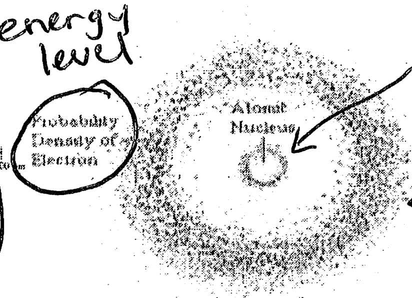
energy levels but...

electrons do not orbit like planets.

Current Model – orbitals and uncertainty principle



energy level



Nucleus

electrons in Electron Cloud

NOTES: How to Calculate the Number of Protons Neutrons and Electrons

Atomic Number Whole # (green) found on Periodic Table (PT), equal to # p^+ (also e^-)

Protons (p^+) equal to atomic #, identity of atom

Electrons (e^-) equal to p^+ in a Neutral atom, ions: $e^- = p^+ - $(charge)

Mass Number (Not on PT), Whole #, mass # = $p^+ + n^0$ } Must have one in order to find other

Neutrons (n^0) (Not on PT) n^0 = mass # $- p^+$

Hyphen Notation – element name – mass #

Examples: Carbon-12, Carbon-13, Carbon-14

Nuclear Symbol –

12 ← mass #, on top (always be larger)

C ← element symbol

(Name) 6 ← atomic #, on bottom (smaller #, from PT)

If given the **hyphen notation**, you must look up the atomic # and then find the number of neutrons using the above equation. (mass # $- p^+ = n^0$) You will already know the number of proton because atomic # equals protons.

Examples:

Phosphorus-32 (mass #)
32 − 15 = 17

$p^+ = 15$
$n^0 = 17$
$e^- = 15$

Isotope - atoms of the same element with different #'s of NEUTRONS.
→ p^+ & e^- will be the same for 2 isotopes
→ # of n^0 (mass # as well) will be different

Phosphorus-31
n^0 = mass # $- p^+$
16 = 31 − 15

$p^+ = 15$
$n^0 = 16$
$e^- = 15$

If given the **nuclear symbol**, you only need to Subtract atomic # from Mass # to find the number of neutrons. You will already know the number of protons because atomic # equals protons.

Examples:

$^{23}_{11}Na$
$p^+ = 11$
$n^0 = 12$
$e^- = 11$

ion → $^{23}_{11}Na^{+1}$
$e^- = 11 - (+1)$
$p^+ = 11$
$n^0 = 12$
$e^- = 10$

* Ion – atoms of the same element with different #'s of ELECTRONS, will have a charge
→ p^+, n^0 will be same for 2 ions

How to write the nuclear symbol: o

mass # or n

Look at the given information and use the periodic table to find the atomic # and element symbol. Write the nuclear symbol for sulfur with 18 neutrons.

Examples: 34 ← mass # = $p^+ + n^0$

34 = 16+18

S ← look up

16 ← look up

$^{34}_{16}S$

How to write the hyphen notation: (name)

n^0

Look at the given information which must include the number of neutrons and use the periodic table to find the atomic #. Write the hyphen notation for a barium atom with 80 neutrons. Then, write the hyphen notation for an atom with 54 protons and 76 neutrons.

Examples: Barium — mass #

Barium-136

mass # = $p^+ + n^0$ = 56+80

Xenon

Xenon-130

54+76

Problems:

1. e^-, p^+, n^0 for hydrogen-3 ________________

2. e^-, p^+, n^0 for cadmium-114 ________________

3. e^-, p^+, n^0 $^{70}_{31}Ga$ ________________

4. e^-, p^+, n^0 $^{86}_{38}Sr$ ________________

5. Write a nuclear symbol for a selenium atom with 42 neutrons. ________________

6. Write a hyphen notation for a cesium atom with 86 neutrons. ________________

7. Write a nuclear symbol for a silver atom with 58 neutrons. ________________

8. Write a hyphen notation for a yttrium atom with 50 neutrons. ________________

9. Write a nuclear symbol for an atom that has 13 protons and 15 neutrons. ________________

10. Write a hyphen notation for an atom that has 26 protons and 28 neutrons. ________________

Average Atomic Mass Notes

Average atomic mass is a weighted average of all the masses of each different isotope for a given atom.

To calculate average atomic mass:

[mass of isotope 1 X % abundance of isotope in decimal form] + [mass of isotope 2 X % abundance of isotope in decimal form] + ...

Same element, Different #'s of n°

Mass can be in grams OR atomic mass units – your procedure will be the same

Percent abundance will be given as a percentage (example 42.389%). To convert to a decimal, move the decimal point TWO PLACES TO THE LEFT.

Checking your work!

a. Your answer should NOT be OUTSIDE the range of numbers for the mass.
b. Your answer should be NEAREST to the mass of the isotope with the GREATEST percent abundance.

Example: Silicon

Isotope #1 (Silicon – 28) has a percent abundance of 92.23%. We convert this to a decimal form by moving the decimal 2 places to the left to get 0.9223. It has a mass of 27.9769265325 amu. Using a calculator, multiply 0.9223 by 27.9769265325. Do NOT round the answer you get yet! Write down every digit the calculator gives you.

0.9223 * 27.9769265325 = 25.80311934amu

Isotope #2 (Silicon – 29) has a percent abundance of 4.67%. We convert this to a decimal form by moving the decimal 2 places to the left to get 0.0467. If you get 0.467, it is because you didn't move it TWO places! This is a common mistake when dealing with a percent that is less than 10. The mass of this isotope is 28.976494700 amu. What should you multiply together?

0.0467 * 28.976494700 = 1.353202302 amu

Isotope #3 (Silicon – 30) has a percent abundance of 3.10%. What is this in decimal form? 0.0310. This isotope has a mass of 29.97377017 amu.

0.0310 * 29.97377017 = 0.929186875amu

Finally, you must add all the little "pieces" you calculated above together to get the average atomic mass! Then you may round your answer to the nearest thousandths place.

25.80311934 + 1.353202302 + 0.929186875 = 28.085508852amu

Answer 28.086 amu

Average Atomic Mass Example Problems

Calculate the average atomic mass for the following element. Show all your work in the space below and be sure not to round until your final answer. Check your work to see if your answer makes sense!

Isotope	Mass (amu)	% Abundance
Lithium-6	6.01512	7.5
Lithium-7	7.01600	92.5

Average atomic mass for Lithium ______________________

Isotope	Mass (amu)	% Abundance
Chromium-50	49.94604	4.345
Chromium-52	51.94050	83.789
Chromium-53	52.94065	9.501
Chromium-54	53.93888	2.365

Average atomic mass for Chromium ________________________

Finally, there is one last point to make. You can determine which is the MOST abundant isotope just by looking at the periodic table.

a. Look up the atomic mass for the element.
b. Round that number to the nearest whole number.
c. That whole number will be the MASS NUMBER for the most common isotope.

Try this for the three elements listed above and see if, by rounding we can match the isotope with the greatest percent abundance.

Runtium Lab

Purpose: The purpose of this lab is to model how the average atomic mass on the periodic table is calculated for an element. In our lab, we are using the element "runtium". You will receive a sample of the element; it has 5 isotopes (5 different colored candies).

What is an isotope of an atom? ____

____

Recall the equation to calculate Average Atomic Mass: aam = (Mass of Isotope 1 x % Abundance *in decimal form* of Isotope 1) + (Mass of Isotope 2 x % Abundance *in decimal form* of Isotope 2) + (Mass of Isotope 3 x % Abundance *in decimal form* of Isotope 3) + ...

Mass: The mass of the isotope you will determine by massing one individual isotope (one individual piece of candy).

% Abundance: The % Abundance will be determined by taking the number of one isotope and dividing by the total number in the sample and multiplying by one hundred. (example: You have 8 bananas / 16 runts total = .5 x 100 = 50% bananas)

Average Atomic Mass: This will be calculated by plugging in the mass and % abundance into the formula above. This represents the mass that would be on the periodic table if "runtium" with its 5 isotopes was a real element.

Data Table:

Color	**Orange**	**Green**	**Purple**	**Yellow**	**Red**
Mass (g)					
Percent Abundance					

Show work for Average Atomic Mass, include units:

Questions:

1. What was your calculated "runtium" average atomic mass? ____________
2. What subatomic particle (electron, proton or neutron) is the same in all isotopes of one element? ____________
3. What subatomic particle (electron, proton or neutron) is different in all isotopes of one element? ____________
4. By changing that particle (electron, proton or neutron) from the question above, what else does that change for that isotope? ____________

Nuclear Decay Notes

- The nuclei of most atoms are stable.
- Radioactive nuclei are unstable and emit radiation to become more stable.
- What would a nucleus be unstable?
  - neutron to proton ratio too low
  - neutron to proton ratio too high
  - nuclei in excited state
  - nuclei too heavy
- What happens?
  - nuclei decay (break down) in different ways
    - Alpha (α) particle emission
      - "fast moving helium atom"
      - $^{4}_{2}He$ (protons 2 neutrons 2 electrons 2)
      - Only able to get through thin sheets of paper and a few cm of air
    - Beta (β) particle emission
      - "fast moving electron"
      - $^{0}_{-1}\beta$ (protons 0 neutrons 0 electrons 1)
      - neutron is converted into proton and electron, electron is shot out of nucleus because electrons cannot exist in the nucleus
      - only able to get through a few mm of aluminum and 100 cm of air
    - Gamma (γ) ray
      - $^{0}_{0}\gamma$ (protons 0 neutrons 0 electrons 0)
      - Electromagnetic radiation (not a particle)
      - able to travel through matter
        - large distances of air
        - several cm of lead
- In a certain sample, all radioactive nuclei do not decay at one time – a random event (as much chance of happening as not happening)
  - Half-life – the amount of time for half instable nuclei to decay and become more stable
  - Unique to all radioactive elements

Nuclear Equations Practice

Remember:
$^{mass\,\#}_{atomic\,\#}X$ (X = chemical symbol)

#p+ = atomic #
#e- = atomic #
#no = mass # - atomic #

atomic # tells you the type of element

1. **Emits α particle**
   a. original mass # - 4 = new mass number
   b. original atomic # - 2 = new atomic number – change the chemical symbol
   c. example:

2. **Emits β particle**
   a. original mass # = new mass number
   b. original atomic # +1 = new atomic number – change the chemical symbol
   c. example:

3. **Emits γ ray**
   a. original mass # = new mass number
   b. original atomic # = new atomic number – do NOT change the chemical symbol
   c. example:

4. **Nucleus gets hit by neutron**
   a. original mass # +1 = new mass number
   b. original atomic # = new atomic number – do NOT change the chemical symbol
   c. example:

To check you work:
- Sum of all mass numbers on both sides of arrow should be equal
- Sum of all atomic numbers on both sides of arrow should be equal
- Illustrates the Law of Conservation of Matter

Your Turn:
1. $^{222}_{86}Rn \rightarrow {}^{4}_{2}\alpha$ + ____________
2. $^{214}_{82}Pb \rightarrow {}^{0}_{-1}\beta$ + ____________
3. $^{9}_{4}Be + {}^{4}_{2}\alpha \rightarrow {}^{1}_{0}n$ + ____________
4. $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{235}_{92}U$ + ____________ $+ 3\,{}^{1}_{0}n$
5. $^{14}_{7}N + {}^{4}_{2}\alpha \rightarrow {}^{18}_{9}F \rightarrow {}^{1}_{1}H$ + ____________

Nuclear Fission and Fusion

What is Fission?

A nuclear reaction in which a large nucleus splits spontaneously or on impact with another particle, producing smaller nuclei, neutrons and a large amount of energy

Applications of fission reactions

Is used to produce electricity as an alternative to coal power plants. Fuel used for these reactions are Uranium - 235. This is a naturally occurring substance that is mined from the ground and must be enriched (concentrated) to produce the Uranium which can undergo fission reactions. Uranium nuclei are bombarded with neutrons to begin a chain reaction. It takes very little energy to begin the process, but it releases a million times more energy than chemical reactions. The smaller nuclei produced from this reaction are also radioactive, with long half-lives, and continue to emit radiation for thousands of years.

Also used to produce the atomic bombs dropped at the end of WWII on Japan.

What is Fusion?

A nuclear reaction in which two low mass nuclei collide at high speeds and fuse to produce one heavier nucleus and a large amount of energy

Applications of fusion reactions

Fusion occurs naturally on the sun and is how the sun's energy is produced. Fusion occurs with low mass elements like hydrogen. Occurs at temperatures in the millions of degrees because there must be enough energy to over come electrostatic repulsion of two protons in order for them to fuse. The energy from a fusion reaction is 3-4 times greater than a fission reaction.

Fusion reactions were "triggered" by fission reactions in the H-bomb (hydrogen bomb) of WWII

Cold Fusion is a hypothetical fusion reaction that is said to take place at room temperature. A couple of scientists in the 80s claimed to have done it; no one else could replicate and confirm their results.

Pros and Cons of Nuclear Fission

Use the following website to fill in the table below: http://dsc.discovery.com/tv-shows/curiosity/topics/10-pros-cons-nuclear-power.htm

	Pros	Cons
10. Environmental Impact	Doesn't produce smoke, produces steam not CO_2.	Requires the mining of Uranium which has be imported. Waste is radioactive.
9. Support	Some countries support its use.	Many people have fear associated with it.
8. Cost-effectiveness	Produces more kilowatts/cents than Coal, wind or solar. Produces jobs.	Construction costs are high + long term storage of waste is expensive.
7. Economics in Developing Nations	Wouldn't have to rely on fossil fuels and wouldn't increase CO_2 to meet needs.	Still have to solve problems of power grid, skilled labor + governments.
6. Proliferation	Hard to steal uranium from power plant if security is adequate.	Could use uranium for bombs instead of power.
5. Reprocessing	Can use spent fuel in the reactor to reduce the 1/2 life of waste.	Expensive to re-process + make reactors to use it, still produces radioactive waste.
4. Safety	Safer than coal burning power plants. Have concrete containment structures.	Meltdowns have occurred. Radiactive water leaches into ground.
3. Impact on Wildlife	Uses less land (destroys less habitat) to produce energy than other reaewable resources.	Hot water released to cool, changes ecosystems, + animals can be sucked into filters
2. Health	No significant connection between living near a nuclear power plant + cancer.	Exposure to radiation can kill. Some areas show increased cancer near plants.
1. The fight against global warming	Produces more clean energy than other renewable resources. More reliable than wind or solar.	Plants take too long to build in order to solve global warming. Uranium is non-renewable.

A one or two letter symbol found on the periodic table, unique to every element	A notation that gives the name of the element and the mass number	Negatively charged subatomic particles found outside of the nucleus	Composed of a small, dense, positively charged nucleus and surrounded by a cloud of negatively charged electrons. Makes up all matter.	The sum of the protons and neutrons in an atom's nucleus
An calculated average of all the masses of each different isotope for a given atom	A fast moving helium atom	The particles that are smaller than an atom and make up its structure	A notation that gives the mass number, atomic number, and element symbol	Electromagnetic radiation emitted during radioactive decay. Able to travel through matter
The number of protons found in an atom is equal to this. Also tells you the number of electrons in a neutral atom	Atoms of the same element with different numbers of neutrons in their nuclei	the amount of time for half unstable nuclei to decay and become more stable	A fast moving electron	Neutrally charged subatomic particles found inside the nucleus
Positively charged subatomic particles found inside the nucleus	When unstable nuclei break down, emitting particles or energy to become more stable	The splitting of a larger atom into two or more smaller ones, producing a lot of energy	The fusing of two or more lighter atoms into one larger one, producing a lot of energy.	