Atoms and Their Isotopes

Why?

Atoms and isotopes are identified by the numbers of protons, neutrons and electrons that they contain. Before you can understand the properties of atoms, how atoms combine to form molecules, and the properties of molecules, you must be familiar with the number of protons, neutrons and electrons associated with atoms.

Success Criteria

- Identify the composition of atoms and their isotopes in terms of the numbers of protons, neutrons, and electrons.
- Use atomic symbols to represent different atoms and their isotopes.
- Efficient use of Periodic Table as a source of data.

Resources

- Periodic Table

Information

From the perspective of a chemist, the entire world is composed of atoms, and atoms are composed of protons, neutrons and electrons. Protons and neutrons are about 2000 times heavier than an electron. A proton has a charge of +1, a neutron has no charge and an electron has a charge of -1. The nucleus is very dense and very small compared to the entire atom.

The properties of atoms are determined by the numbers of protons, neutrons and electrons that they contain. Atoms with the same number of protons but different number of neutrons are called isotopes of an element.

The isotopic notation for an atom includes the following information: symbol of the element, the element's atomic number (Z) which specifies the number of protons in the nucleus, and the mass number (A) which indicates the number of protons plus neutrons in the nucleus. [The number of electrons in a neutral atom is equal to the number of protons in the nucleus of the atom. The mass contributed by the electrons in an atom is very small, so it is not included when calculating the mass number.]

Atomic Symbol Notation

$$^{A}_{Z}X$$

Mass Number (protons + neutrons)
Atomic Symbol
Atomic Number (protons)

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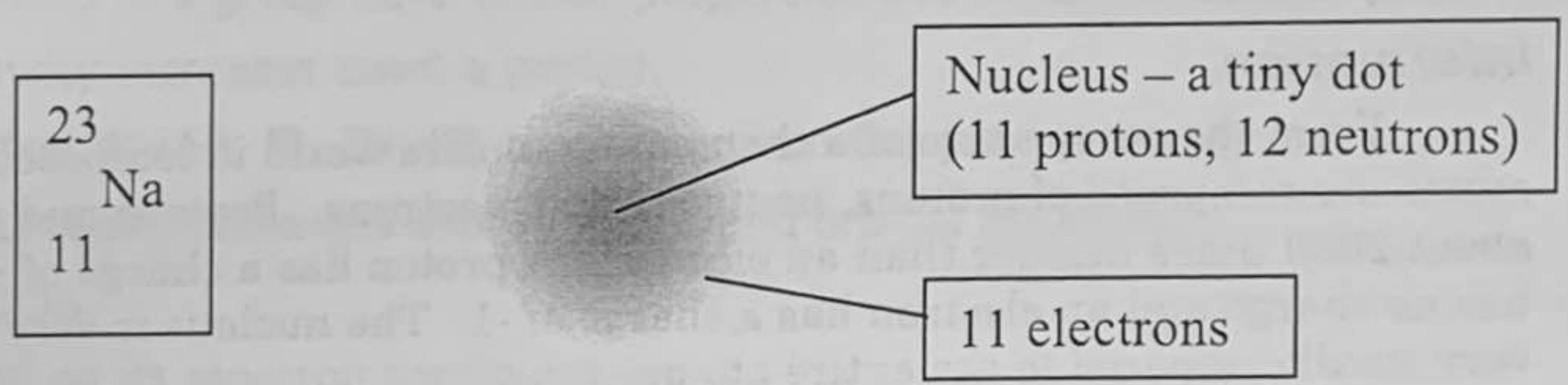
Subatomic Particles

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

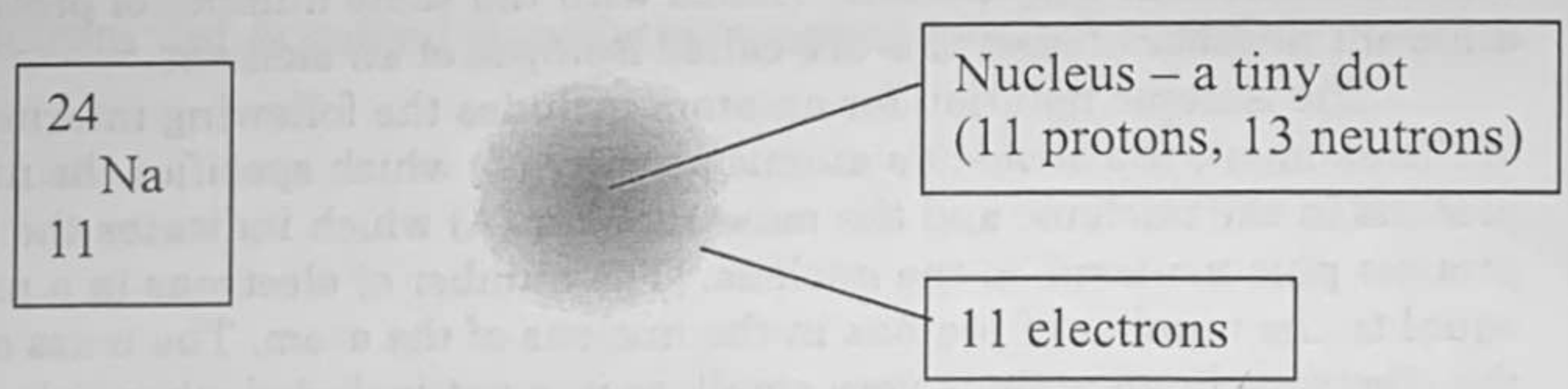
Model: Two Isotopes of Sodium

The diagrams below show representations of sodium isotopes. [Note: the diameter of an atom is about 10,000 times larger than the diameter of the atomic nucleus so the relative sizes of the atom and the nucleus are not accurately depicted in these diagrams.]

Isotope 1



Isotope 2



Key Questions

1. What information is provided by the atomic number, Z?

# of protons

2. What information is provided by the mass number, A?

protons + neutrons

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What is the relationship between the number of protons and the number of electrons in an atom?

they are the same

Because of the relationship between the number of protons and number of electrons in an atom, what is the electrical charge of an atom?

0

5. Where are the protons and neutrons located in an atom?

nucleus

6. What do the two sodium isotopes shown in the model have in common with each other?

# of protons

7. How do the two sodium isotopes shown in the model differ from each other?

# of neutrons + mass #

8. What distinguishes an atom of one element from an atom of another element?

# of protons

Exercises

1. Describe the similarities between $^{35}_{17}Cl$, and $^{37}_{17}Cl$.

symbol, # of protons

2. Describe the differences between $^{35}_{17}Cl$, and $^{37}_{17}Cl$.

mass # + # of neutrons

3. Write the atomic symbols for two isotopes of carbon, C, one with 6 neutrons and the other with 7 neutrons.

$^{12}_{6}C$ $^{13}_{6}C$

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4. Use a periodic table to fill in the missing information in the following table.

Name	Symbol	Atomic Number Z (p)	Mass Number A (p+n)	Number of Neutrons	Number of Electrons
oxygen	$^{16}_{8}O$	8	16	8	8
nitrogen	$^{14}_{7}N$	7	14	7	7
sulfur	$^{34}_{16}S$	16	34	18	16
hydrogen	$^{2}_{1}H$	1	2	1	1
hydrogen	$^{3}_{1}H$	1	3	2	1
magnesium	$^{24}_{12}Mg$	12	24	12	12
magnesium	$^{25}_{12}Mg$	12	25	13	12
uranium	$^{238}_{92}U$	92	238	146	92
krypton	$^{84}_{36}Kr$	36	84	48	36

Problems

1. The radius of a Cl nucleus is 4.0 fm, and the radius of a Cl atom is 100 pm. (1 fm = 1 x 10^{-15} m, 1 pm = 1 x 10^{-12} m). How many times larger is the diameter of the Chlorine atom than the diameter of the Chlorine nucleus?

2. Identify two objects that have this same ratio of lengths.

3. How many times larger is the volume of the atom than the volume of the nucleus?

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History of the Atomic Structure: People and Experiments

Watch "The History of the Atomic Theory": http://tinyurl.com/q84jf9g & complete the following:

The Beginning of the Atomic Theory:

Democritis was the first person to come up with the idea of an atom

Aristole believed that matter was not made up of tiny particles, but of five basic elements

1. water
2. earth
3. air
4. fire
5. aether

Was Aristotle or Democritus' idea more prevalent at their time?

Aristotle

What did Aristotle and Democritus' ideas lack?

experimental evidence

The 1800's and Beyond: Dalton

Dalton established the atomic theory with five major points:

1. All matter is composed of atoms
2. Atoms cannot be created or destroyed
3. All atoms of the element are identical
4. chemical reactions occur when atoms are rearranged
5. Compounds are formed by the combination of two or more different kinds of atoms.

Did John Dalton agree with Democritus that atoms are indivisible?

yes

The 1800's and Beyond: Thompson

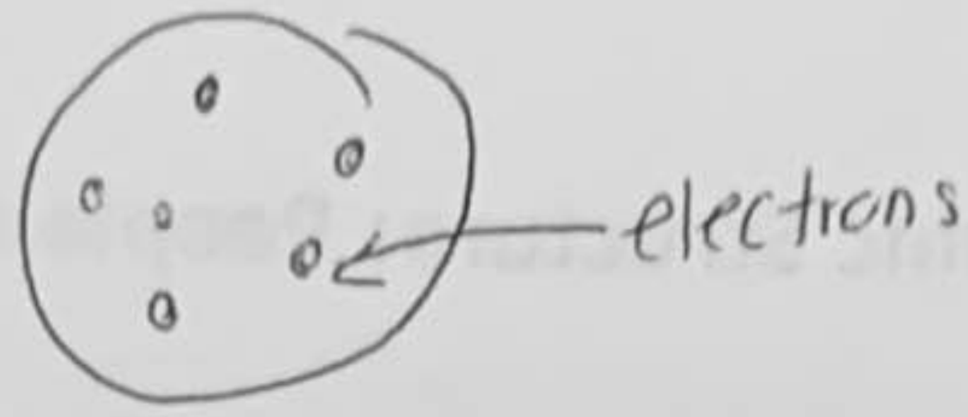
JJ Thompson discovered the negatively charged part of an atom which is the electrons.

He discovered negatively charged particles by using a cathode ray tube

JJ Thompson called his theory the plum pudding model, which looks like a chocolate chip cookie.

What do the chocolate chip cookies represent in his model?

Draw the plum pudding model:



The 1800's and Beyond: Rutherford

Ernest Rutherford is responsible for discovering the positively charged particle of an atom called the protons.

He shot alpha particles (which are dense positive particle) at a thin sheet of gold foil. He and his team expected the particles to go through the atom which was based off the JJ Thompsons model.

In actuality, some of the particles passed and some were reflected back. They believed that there must have been a massive positively charged particle at the center of the atom.

Rutherford is known for discovering that the atom contained a nucleus (dense center) which was positively charged and it was made up of mostly empty space

The 1800's and Beyond: Bohr

Bohr is responsible for the transition of the modern view of the atom

Bohr found that electron travel around the center at discrete energy levels

A quantum is the amount of energy needed for one electron to move to another energy level

The Beginning of the Modern Atomic Theory

De Broglie proposed that electrons act more like waves than particles

The Heisenberg Uncertainty Principle states that you cannot know the both and speed of an electron at the same time

Schrodinger developed a mathematical equation to represent where electrons are located around the central nucleus of an atom

Schrodinger showed us that we can only know the probability of finding an electron in a certain region. This is known as the election cloud model.

James Chadwick discovered the neutron which is located in the nucleus of the atom with the protons.

Which version of the model is accepted today?

election cloud model

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History of the Atom Worksheet

John Dalton (1766 – 1844):

John Dalton was an English chemist. His ideas form the atomic theory of matter. Here are his ideas.

A. All elements are composed (made up) of atoms.
B. Atoms are indivisible.
C. All atoms of the same elements are alike. (One atom of oxygen is like another atom of oxygen.)
D. Atoms of different elements are different. (An atom of oxygen is different from an atom of hydrogen.)
E. Atoms of different elements combine to form a compound. These atoms have to be in definite whole number ratios. For example, water is a compound made up of 2 atoms of hydrogen and 1 atom of oxygen (a ratio of 2:1). Three atoms of hydrogen and 2 atoms of oxygen cannot combine to make water.

1. Which of the above statements is/are false? C,
2. What discovery/discoveries proved them to be false? /

2. What are elements made of? atoms
3. An atom of hydrogen and an atom of carbon are compounds.
4. What are compounds made of? different elements
5. The ratio of atoms in HCl is: a) 1:3 b) 2:1 (c) 1:1

J. J. Thompson (Late 1800s):

J. J. Thompson was an English scientist. He discovered the electron when he was experimenting with gas discharge tubes. He noticed a movement in a tube. He called the movement cathode rays. The rays moved from the negative end of the tube to the positive end. He realized that the rays were made of negatively charged particles – electrons.

1. What did J.J. Thompson discover? electrons
2. What is the charge of an electron? –
3. Why do electrons move from the negative end of the tube to the positive end?
because they have a negative charge

+, – attract
–, – repel

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Lord Ernest Rutherford (1871 – 1937):

Ernest Rutherford conducted a famous experiment called the gold foil experiment. He used a thin sheet of gold foil. He also used special equipment to shoot alpha particles (positively charged particles) at the gold foil. Most particles passed straight through the foil like the foil was not there. Some particles went straight back or were deflected (went in another direction) as if they had hit something. The experiment shows:

- Atoms are made of a small positive nucleus; positive nucleus repels (pushes away) positive alpha particles
- Atoms are mostly empty space

1. What is the charge of an alpha particle? +
2. Why is Rutherford's experiment called the gold foil experiment? he shot alpha particle through gold foil
3. How did he know that an atom was mostly empty space? some went straight through (most)
4. What happened to the alpha particles as they hit the gold foil? some went through, some deflected back, others got deflected in another direction
5. How did he know that the nucleus was positively charged? the alpha particles repelled the nucleus

Niels Bohr (Early 1900s):

Niels Bohr was a Danish physicist. He proposed a model of the atom that is similar to the model of the solar system. The electrons go around the nucleus like planets orbit around the sun. All electrons have their energy levels – a certain distance from the nucleus. Each energy level can hold a certain number of electrons. Level 1 can hold 2 electrons, Level 2 - 8 electrons, Level 3 - 18 electrons, and level 4 – 32 electrons. The energy of electrons goes up from level 1 to other levels. When electrons release (lose) energy they go down a level. When electrons absorb (gain) energy, they go to a higher level.

1. Why could Bohr's model be called a planetary model of the atom? the electrons circle the nucleus like the planets circle the sun
2. How do electrons in the same atom differ? they have different energies
3. How many electrons can the fourth energy level hold? 32
4. Would an electron have to absorb or release energy to jump from the second energy level to the third energy level? absorb
5. For an electron to fall from the third energy level to the second energy level, it must release energy.

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Name: Notes on Atomic Structure Date: ____________ Class Pd. ______

Parts of the Atom Practice

Symbol	Atomic Number	Mass Number	Number of Protons	Number of Neutrons	Number of Electrons
$^{20}_{10}Ne$	10	20	10	10	10
$^{56}_{26}Fe$	26	56	26	30	26
$^{55}_{25}Mn^{+2}$	25	55	25	30	23
$^{198}_{79}Au^{+1}$	79	198	79	119	78
$^{206}_{82}Pb$	82	206	82	124	82
$^{108}_{47}Ag^{+1}$	47	108	47	61	46
$^{84}_{37}Rb$	37	84	37	47	37
$^{127}_{53}I^{-1}$	53	127	53	74	54
$^{9}_{4}Be^{+2}$	4	9	4	5	2
$^{222}_{86}Rn$	86	222	86	136	86
$^{196}_{78}Pt$	78	196	78	118	78
$^{91}_{40}Zr$	40	91	40	51	40
$^{59}_{28}Ni$	28	59	28	31	28
$^{34}_{17}Cl^{-1}$	17	34	17	17	18
$^{118}_{50}Sn$	50	118	50	68	50
$^{19}_{9}F^{-1}$	9	19	9	10	10
$^{58}_{38}Sr$	38	58	38	20	38
$^{40}_{19}K^{+1}$	19	40	19	21	18
$^{223}_{87}Fr$	87	223	87	136	87

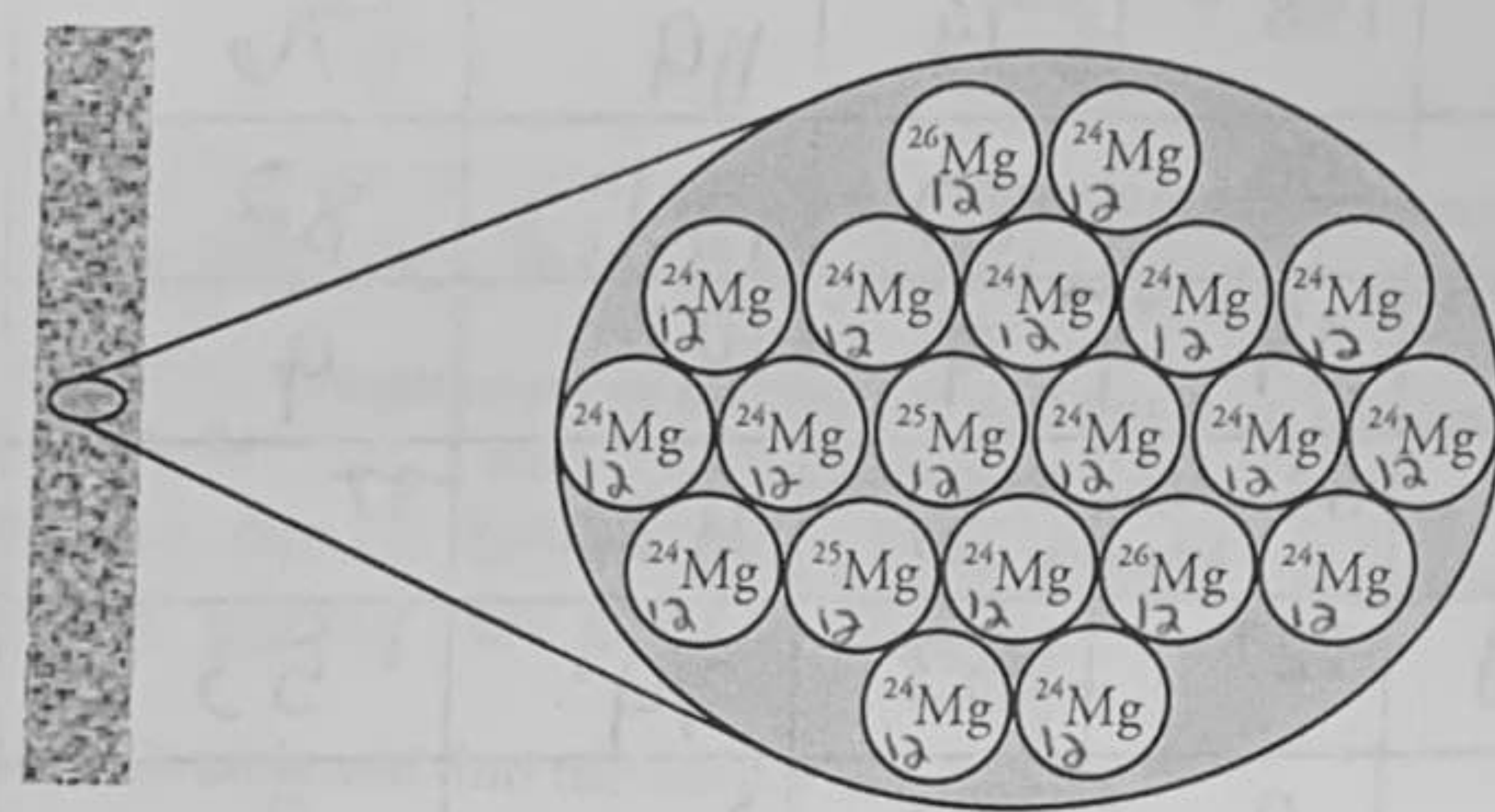
Average Atomic Mass

How are the masses on the periodic table determined?

Why?

Most elements have more than one naturally occurring isotope. As you learned previously, the atoms of those isotopes have the same atomic number (number of protons), making them belong to the same element, but they have different mass numbers (total number of protons and neutrons) giving them different atomic masses. So which mass is put on the periodic table for each element? Is it the most common isotope's mass? The heaviest mass? This activity will help answer that question.

Model 1 – A Strip of Magnesium Metal



1. Write in the atomic number for each Mg atom in Model 1.

2. What are the mass numbers of the naturally occurring isotopes of magnesium shown in Model 1?

   24, 25, 26

3. Do all of the atoms of magnesium in Model 1 have the same atomic mass? Explain.

   No. They differ from 24-26.

4. For the sample of 20 atoms of magnesium shown in Model 1, draw a table indicating the mass numbers of the three isotopes and the number of atoms of each isotope present.

mass #	quantity
24	16
25	2
26	2

5. Which isotope of magnesium is the most common in Model 1?

   $^{24}_{12}Mg$

6. Based on Model 1 and the table you created in Question 4, for every 10 atoms of magnesium, approximately how many atoms of each isotope will be found?

   24: 8 25: 1 26: 1

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Model 2 – Natural Abundance Information for Magnesium

Isotope	Natural Abundance on Earth (%)	Atomic Mass (amu)
^{24}Mg	78.99	23.9850
^{25}Mg	10.00	24.9858
^{26}Mg	11.01	25.9826

7. Consider the natural abundance information given in Model 2.
   a. Calculate the expected number of atoms of each isotope that will be found in a sample of 20 atoms of Mg. *Hint:* The number of atoms must be a whole number!

   24 Mg → 16   25 Mg → 2   26 Mg → 2

   b. Is Model 1 accurate in its representation of magnesium at the atomic level? Explain.

   yes because they are in the correct ratio

8. If you could pick up a single atom of magnesium and put it on a balance, the mass of that atom would most likely be ______ amu. Explain your reasoning.

   23.9850 amu because it is most abundant, so we are more likely to pick 24 Mg

9. Refer to a periodic table and find the box for magnesium.
   a. Write down the decimal number shown in that box.

   24.31

   b. Does the decimal number shown on the periodic table for magnesium match any of the atomic masses listed in Model 2?

   No

10. The periodic table does not show the atomic mass of every isotope for an element.
    a. Explain why this would be an impractical goal for the periodic table.

    Because all the elements have many naturally occuring isotopes

    b. Is it important to the average scientist to have information about a particular isotope of an element? Explain.

    No because scientists can't pick out which specific atom they are getting.

11. What would be a practical way of showing the mass of magnesium atoms on the periodic table given that most elements occur as a mixture of isotopes?

    average

12. Propose a possible way to calculate the average atomic mass of 100 magnesium atoms. Your answer may include a mathematical equation, but it is not required.

    multiple the mass by the percent it occurs and divide by 100

STOP

this is how we find average atomic mass

Model 3 – Proposed Average Atomic Mass Calculations

*

Mary's Method

$$\frac{(78.99)(23.9850 \text{ amu}) + (10.00)(24.9858 \text{ amu}) + (11.01)(25.9826 \text{ amu})}{100} = \underline{24.31}$$

*

Jack's Method

$$(0.7899)(23.9850 \text{ amu}) + (0.1000)(24.9858 \text{ amu}) + (0.1101)(25.9826 \text{ amu}) = \underline{24.31}$$

Alan's Method

$$\frac{23.9850 \text{ amu} + 24.9858 \text{ amu} + 25.9826 \text{ amu}}{3} = \underline{24.98}$$

13. Complete the three proposed calculations for the average atomic mass of magnesium in Model 3.

14. Consider the calculations in Model 3.

   a. Which methods shown in Model 3 give an answer for average atomic mass that matches the mass of magnesium on the periodic table?

   Mary's and Jack's method

   b. Explain why the mathematical reasoning was incorrect for any method(s) in Model 3 that did not give the correct answer for average atomic mass (the one on the periodic table).

   Alan's method did not take into account how often the isotopes occur.

   c. For the methods in Model 3 that gave the correct answer for average atomic mass, show that they are mathematically equivalent methods.

   $$\frac{78.99}{100} = 0.7899$$

15. Use one of the methods in Model 3 that gave the correct answer for average atomic mass to calculate the average atomic mass for oxygen. Isotope information is provided below. Show all of your work and check your answer against the mass listed on the periodic table.

Isotope	Natural Abundance on Earth (%)	Atomic Mass (amu)
^{16}O	99.76	15.9949
^{17}O	0.04	16.9991
^{18}O	0.20	17.9992

$$(.9976 \times 15.9949) + (.0004 \times 16.9991) + (0.0020 \times 17.9992)$$
$$= 15.9993 \text{ amu}$$

STOP

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Read This!

Recall that all isotopes of an element have the same physical and chemical properties, with the exception of atomic mass (and for unstable isotopes, radioactivity). Therefore, the periodic table lists a weighted **average atomic mass** for each element. In order to calculate this quantity, the natural abundance and atomic mass of each isotope must be provided.

16. Consider the individual atomic masses for magnesium isotopes given in Model 2.

   a. Which isotope has an atomic mass closest to the average atomic mass listed on the periodic table?

   24 Mg

   b. Give a mathematical reason for your answer to part *a*.

   since we are multiplying it by the occurance it should be closest to the largest quantity

17. Boron has two naturally occurring isotopes: boron-10 and boron-11. Which isotope is more abundant on Earth? Use grammatically correct sentences to explain how your group determined the answer.

   "B is more abundant on Earth since the average atomic mass is closer to 11 than 10.

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Atomic Structure

Symbol	Atomic Number	Mass Number	Number of Protons	Number of Neutrons	Number of Electrons	Charge
$^{108}Ag^{+1}$	47	108	47	61	46	+1
$^{56}Fe^{+3}$	26	56	26	30	23	+3
$^{80}Br^{-1}$	35	80	35	45	36	-1
$^{198}_{79}Au^{+3}$	79	198	79	119	76	+3
^{206}Pb	82	206	82	124	82	0
^{19}F	9	19	9	10	9	0
$^{84}_{37}Rb$	37	84	37	47	37	0
^{127}I	53	127	53	74	53	0
$^{9}Be^{+2}$	4	9	4	5	2	+2
$^{16}O^{-2}$	8	16	8	8	10	-2
$^{196}Pt^{+4}$	78	196	78	118	74	+4
$^{91}Zr^{+2}$	40	91	40	51	38	+2
^{59}Ni	28	59	28	31	28	0
$^{34}_{17}Cl^{-1}$	17	34	17	17	18	-1
^{118}Sn	50	118	50	68	50	0
$^{32}S^{-2}$	16	32	16	16	18	-2
$^{58}Sr^{+2}$	38	58	38	20	36	+2
$^{40}_{19}K$	19	40	19	21	19	0
^{223}Fr	87	223	87	136	87	0

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key

MAGIC NUMBER: HISTORY OF THE ATOM

Directions: Put the number of the definition from the list below into the square with the appropriate term. Check your answers by adding the numbers to see if all the sums of all rows, both across and down add up to the same number, the Magic #.

Democritus 2	Dalton 7	Thomson 18	Chadwick 12	Total 39
Rutherford 8	Proton 5	Atom 11	Bohr 15	39
Wave Model 13	Neutron 17	Nucleus 6	Alpha particle 3	39
Electron 16	Model 10	Energy levels 4	Electron cloud 9	39
Total 39	39	39	39	

Magic Number 39

1. ~~Represented by a symbol; all are found on the Periodic Table~~
2. Made a mental model of the atom; Greek philosopher
3. Used by Rutherford in his experiment; made of two protons and two neutrons
4. The paths in which electrons circle the nucleus according to the Bohr model
5. The positive particle in the nucleus of an atom
6. The tiny positive core of an atom; contains protons and neutrons
7. Formed the atomic theory model of the atom; English schoolteacher
8. Discovered the nucleus using his gold foil experiment
9. Current explanation of where electrons might be found in the atom
10. Used by scientists to explain something we can not see or understand
11. The smallest particle of an element that has the properties of that element
12. Discovered the neutron
13. Current model of the atom; proposed by Schrodinger
14. ~~Mass of protons and neutrons~~
15. Developed the model of the atom in which electrons orbit the nucleus in energy levels
16. The negative particle that circles the nucleus
17. The neutral particle in the nucleus of an atom
18. Proposed the "plum-pudding" model of the atom; discovered the electron

Three isotopes of argon occur in nature, Ar-36, Ar-38, Ar-40. If the relative atomic masses and abundances of each of these isotopes are as follows, calculate the average atomic mass of argon: Ar-36 (35.968 amu, 0.337%); Ar-38 (37.963 amu, 0.063%); and Ar-40 (39.962 amu, 99.600%)

(35.968 x .00337) + (37.963 x .00063) + (39.962 x .99600)

= 39.947 amu

honors → 40. amu

2. If naturally occurring boron is 80.20% B-11 (atomic mass = 11.009 amu) and 19.80 % of some other isotopic form of boron, what must the atomic mass of this second isotope be in order to account for the 10.811 amu average atomic mass of boron?

10.811 = (11.009 x .8020) + (x x .1980)

1.982 = x · .1980

x = 10.009 amu   honors → 10.01 amu

3. An element X has three isotopes: X-26, X-28, X-29. Calculate the average atomic mass of element X if X-26 has a mass of 25.998 amu and is 20.33% abundant, X-28 has a mass of 28.003 amu and is 5.99% abundant, and X-29 has a mass of 28.986 amu and is 73.68% abundant.

(25.998 x .2033) + (28.003 x .0599) + (28.986 x .7368)

= 28.320 amu

honors → 28.3 amu

Identify Element X: Silicon

4. Oxygen has three naturally occurring isotopes: O-16 (15.995 amu; 99.762%), O-17 (16.999 amu; 0.038%), and O-18 (17.999 amu; 0.200%). Calculate the average atomic mass of oxygen.

(15.995 x .99762) + (16.999 x .00038) + (17.999 x .00200)

= 15.999 amu   honors → 16 amu

5. Find the average atomic mass for Li if 7.5% of Li atoms are ^{6}Li with a mass of 6.015 amu, 92.5% are ^{7}Li with a mass of 7.016 amu.

$(6.015 \times .075) + (7.016 \times .925)$

6.941 amu

honors → 6.9 amu

6. Find the average atomic mass for Cl if 75.78% of Cl atoms are ^{35}Cl with a mass of 34.969 amu and 24.22% are ^{37}Cl with a mass of 36.966 amu.

$(34.969 \times .7578) + (36.966 \times .2422)$

= 35.453 amu

honors → 35.45 amu

7. Find the average atomic mass for Mg if 78.99% of Mg atoms are ^{24}Mg with a mass of 23.985 amu, 10.00% are ^{25}Mg with a mass of 24.986 amu, and 11.01% are ^{26}Mg with a mass of 25.983 amu.

$(23.985 \times .7899) + (24.986 \times .10000) + (25.983 \times .1101)$

= 24.305 amu

honors → 24.31 amu

8. There are 2 isotopes of copper that occur naturally; ^{63}Cu and ^{65}Cu. The ^{63}Cu atoms have a mass of 62.930 amu and the ^{65}Cu atoms have a mass of 64.928 amu. What is the percent natural abundance for each isotope?

Average atomic mass = 63.55 amu

$x + y = 1 \quad y = 1 - x$

$63.55 = (62.930)x + (64.928)(1-x)$

$63.55 = 62.930x - 64.928x + 64.928$

$-64.928 \quad -64.928$

$-1.378 = 62.930x - 64.928x$

$-1.378 = -1.998x$

$0.6897 = x$

^{63}Cu = 68.97%

65 = 31.03%

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Atomic Structure

CLASSWORK

Part I. Fill in the following table:

ISOTOPIC SYMBOL	NUMBER OF PROTONS	NUMBER OF ELECTRONS	NUMBER OF NEUTRONS	ATOM OR ION?	NET CHARGE
$^{131}_{53}I^{1-}$	53	54	78	Ion	-1
$^{80}_{35}Br^{-1}$	35	36	45	Ion	-1
$^{23}_{11}Na$	11	11	12	Atom	0
$^{45}_{21}Sc^{3+}$	21	18	24	Ion	+3
$^{209}_{84}Po^{+4}$	84	80	125	Ion	+4
$^{91}_{40}Zr^{4+}$	40	36	51	Ion	+4
$^{59}_{27}Co^{+2}$	27	25	32	Ion	+2
$^{133}_{55}Cs$	55	55	78	atom	0

5

Honors Chemistry: Half-life. Solve the following problems.

1. The half-life of an isotope is 2.0 hours. How much of a 50.0 g sample is left after 6.0 hours? (6.25 g)

$\frac{6 \text{ hours}}{2 \text{ hours}} = 3$ cycles

50 → 25 → 12.5 → 6.25g

2. The half-life of an isotope is 10.0 minutes. If 25.0 grams are left after 60.0 minutes, how many grams were in the original sample? (1600 g)

$\frac{60.0 \text{ min}}{10.0 \text{ min}} = 6$ cycles

800 ← 400 ← 200 ← 100 ← 50 ← 25

1600 g

3. If 200.0 g of an isotope decays to 25.0 grams in 24.0 seconds, what is the half-life of this isotope? (8.0 s)

200 → 100 → 50 → 25   3 cycles

$\frac{24.0 \text{ sec}}{3 \text{ cycles}} = 8.0$ sec

4. The half-life of Carbon-14 is about 5730 years. If an artifact had 4.0 grams of C-14 originally, and it now has 1.0 grams of C-14, what is the approximate age of the artifact? (11,400 years)

4 → 2 → 1

5730 × 2 = 11460 years

2 cycles = $\frac{\text{decay length (x)}}{\text{HL (5730)}}$

5. The half-life of radon-222 is 3.8 days. How much of a 100.0 g sample is left after 15.2 days? (6.25 g)

100 → 50 → 25 → 12.5 → 6.25g

$\frac{15.2}{3.8} = 4$ cycles

6. Carbon-14 has a half-life of 5,730 years. If a sample contains 70 mg originally, how much is left after 17,190 years? (8.75 g)

$\frac{17190}{5730} = 3$ cycles

70 → 35 → 17.5 → 8.75g

7. How much of a 500.0 g sample of potassium-42 is left after 62 hours? The half-life of K-42 is 12.4 hours. (15.6 g)

$\frac{62}{12.4} = 5$ cycles

500 → 250 → 125 → 62.5 → 31.25 →

15.6g

8. The half-life of cobalt-60 is 5.26 years. If 50.0 g are left after 15.8 years, how many grams were in the original sample? (400 g)

$\frac{15.8}{5.26} = 3$

400g ← 200 ← 100 ← 50

9. The half-life of I-131 is 8.07 days. If 25 g are left after 40.35 days, how many grams were in the original sample? (800 g)

$\frac{40.35}{8.07} = 5$

800g ← 400 ← 200 ← 100 ← 50 ← 25

10. If 100.0 g of Au-198 decays to 6.25 g in 10.8 days, what is the half-life of Au-198? (2.7 days)

100 →(1) 50 →(2) 25 →(3) 12.5 →(4) 6.25

4 cycles $= \frac{10.8}{x}$

2.7 days

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Balancing Nuclear Equations

Name: ______________________ Period: ______________________

There are two types of nuclear reactions: Fission, where a nucleus breaks into two or more pieces, and fusion where two or more nuclei combine to form a new element. In nuclear reactions, only the nucleu involved. Electrons are ignored. Some atomic nuclei are inherently unstable and spontaneously chang "decay". There are four types of decay:

Type	Symbol	Charge of particle	Mass(AMU)	Effect on Atomic #	Effect on Atomic Mass	Strength
Alpha	α	+2 (He nucleus)	4	decrease by 2	decrease by 4	Stopped pap
Beta- e- emission	β- electron	-1	0	increase by 1	0	Aluminum
Beta+ e- capture	β+ Positron	+1	0	decrease by 1	0	Aluminum
Gamma	γ	none	none	none	none	Lead

The net result of α, β- or β+ decay is a new element. In b- decay, a neutron decays into a p+ and an e- which is then ejected. In β+ decay a p+ captures an e- and transforms into a neutron. But despite the natu of the reaction the law of conservation of matter still applies and the equations are balanced the same way Note α particle is a helium nucleus!

Another type of reaction occurs when something impacts a nucleus. These reactions result either i the nucleus splitting (fission) or the combination of two or more nuclei to form a third, different nucleus (fusion).

Balancing Nuclear Equations: Matter must be conserved including all p+ & n°. Example:

Decay reaction (α decay) $^{219}_{86}Rn \rightarrow ^{4}_{2}He + ^{215}_{84}Po$

Fission Reaction $^{1}_{0}n + ^{235}_{92}U \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3^{1}_{0}n$

Fusion Reaction: $^{35}_{17}Cl + ^{1}_{1}H \rightarrow ^{36}_{18}Ar$ another example $^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + n^{\circ}$

Practice

Fill in the missing symbol and name the reaction:

1. $^{3}_{1}H \rightarrow$ $^{3}_{2}He$ $+ ^{0}_{-1}e$ beta decay
2. $^{232}_{92}U \rightarrow ^{228}_{90}Th +$ $^{4}_{2}He$ alpha decay
3. $^{144}_{58}Ce \rightarrow ^{144}_{59}Pr +$ $^{0}_{-1}e$ beta decay
4. $^{65}_{30}Zn \rightarrow$ $^{65}_{29}Cu$ $+ ^{0}_{+1}e$ positron decay
5. $^{40}_{19}K \rightarrow ^{40}_{18}Ar +$ $^{0}_{1}e$ positron decay

6. ${}^{7}_{4}Be \rightarrow {}^{7}_{4}Be +$ ${}^{0}_{0}\gamma$ gamma decay

~~7. ${}^{1}_{0}n + {}^{235}_{92}U \rightarrow$~~ ${}^{236}_{92}U$ $\rightarrow {}^{141}_{55}Cs + {}^{92}_{37}Rb +$ $3{}^{1}_{0}n$ fission

8. ${}^{222}_{86}Rn \rightarrow$ ${}^{218}_{84}Po$ $+ {}^{4}_{2}He$ alpha decay

9. ${}^{129}_{53}I \rightarrow {}^{129}_{54}Xe +$ ${}^{0}_{-1}e$ beta decay

10. ${}^{239}_{94}Pu \rightarrow$ ${}^{235}_{92}U$ $+ {}^{4}_{2}He$ alpha decay

11 ${}^{15}_{8}O \rightarrow {}^{15}_{7}N +$ ${}^{0}_{1}e$ positron decay

12. Write a balanced nuclear equation for each decay process indicated.

a. The isotope Th-234 decays by an alpha emission.

${}^{234}_{90}Th \rightarrow {}^{4}_{2}He + {}^{230}_{88}Ra$

b. The isotope Fe-59 decays by a beta emission.

${}^{59}_{26}Fe \rightarrow {}^{0}_{-1}e + {}^{59}_{27}Co$

c. The isotope Tc-99 decays by a gamma emission.

${}^{99}_{43}Tc \rightarrow {}^{99}_{43}Tc + {}^{0}_{0}\gamma$

d. The isotope C-11 decays by a electron capture.

${}^{11}_{6}C \rightarrow {}^{0}_{1}e + {}^{11}_{5}B$

Balance these equations: Note ${}^{4}_{2}He$ is the only stable isotope of helium.

13. ${}^{1}_{1}H + {}^{7}_{3}Li \rightarrow$ ${}^{8}_{4}Be$

14. ${}^{7}_{4}Be + {}^{1}_{0}n \rightarrow 2$ ${}^{2}_{1}$ H + ${}^{4}_{2}$ He

15. What is the balanced nuclear equation for the reaction of curium-246 with carbon-12 to produce nobelium-254 and four neutrons?

${}^{246}_{96}Cm + {}^{12}_{6}C \rightarrow 4{}^{1}_{0}n + {}^{254}_{102}No$

16. What is the balanced nuclear equation for the reaction of californium-250 with boron-10 to produce lawrencium-258 and two neutrons?

${}^{250}_{98}Cf + {}^{10}_{5}B \rightarrow 2{}^{1}_{0}n + {}^{258}_{103}Lr$

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NUCLEAR CHEMISTRY

BALANCING NUCLEAR REACTIONS WORKSHEET

Predict the missing product or reactant in the following nuclear reactions. Determine the type of nuclear reaction (α emission, β emission, γ emission, positron emission, ~~artificial transmutation~~, fission, or fusion) described.

Type of Nuclear Reaction

1.) ${}^{42}_{19}K \rightarrow {}^{0}_{-1}e + {}^{42}_{20}Ca$ — 1.) beta decay

2.) ${}^{239}_{94}Pu \rightarrow {}^{4}_{2}He + {}^{235}_{92}U$ — 2.) alpha decay

3.) ${}^{235}_{92}U \rightarrow {}^{4}_{2}He + {}^{231}_{90}Th$ — 3.) alpha decay

4.) ${}^{1}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He$ — 4.) fusion

5.) ${}^{6}_{3}Li + {}^{1}_{0}n \rightarrow {}^{4}_{2}He + {}^{3}_{1}H$ — 5.) alpha decay

6.) ${}^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$ — 6.) fusion

7.) ${}^{9}_{4}Be + {}^{1}_{1}H \rightarrow {}^{6}_{3}Li + {}^{4}_{2}He$ — 7.) ______

8.) ${}^{37}_{19}K \rightarrow {}^{0}_{+1}e + {}^{37}_{18}Ar$ — 8.) position decay

9.) ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3\,{}^{1}_{0}n$ — 9.) fission

10.) ${}^{238}_{92}U + {}^{4}_{2}He \rightarrow {}^{241}_{94}Pu + {}^{1}_{0}n$ — 10.) fusion

11.) ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ — 11.) beta decay

12.) ${}^{187}_{75}Re + {}^{2}_{1}H \rightarrow {}^{188}_{75}Re + {}^{1}_{1}H$ — 12.) ______

13.) ${}^{22}_{11}Na + {}^{0}_{-1}e \rightarrow {}^{22}_{10}Ne$ — 13.) --- fusion

14.) ${}^{218}_{84}Po \rightarrow {}^{214}_{82}Pb + {}^{4}_{2}He$ — 14.) alpha decay

15.) ${}^{253}_{99}Es + {}^{4}_{2}He \rightarrow {}^{1}_{0}n + {}^{256}_{101}Md$ — 15.) fusion

Write the Balanced nuclear equations for the alpha decay of:

a) Plutonium-234 ${}^{234}_{94}Pu \rightarrow {}^{4}_{2}He + {}^{230}_{92}U$

b) Strontium-90 ${}^{90}_{38}Sr \rightarrow {}^{4}_{2}He + {}^{86}_{36}Kr$

Write the balanced nuclear equations for the alpha, beta and gamma decay of Radium-226

${}^{226}_{88}Ra \rightarrow {}^{4}_{2}He + {}^{222}_{86}Rn$ | ${}^{226}_{88}Ra \rightarrow {}^{0}_{-1}e + {}^{226}_{89}Ac$

${}^{226}_{88}Ra \rightarrow {}^{0}_{0}\gamma + {}^{226}_{88}Ra$

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Nuclear Chemistry

(What is radiation?)

Model: Nuclide symbols for three isotopes of carbon

$^{12}_{6}C$	$^{13}_{6}C$	$^{14}_{6}C$
carbon-12	carbon-13	carbon-14

Critical Thinking Questions:

1. How many protons are in carbon-12? 6 How many neutrons are in carbon-12? 6
2. How many protons are in carbon-13? 6 How many neutrons are in carbon-13? 7
3. How many protons are in carbon-14? 6 How many neutrons are in carbon-14? 8
4. Make a list of what is the same and what is different among isotopes.

   Same: protons, element, charge | different: nuetrons, mass #

5. What does the subscripted 6 represent in all three nuclide symbols in the Model?

   Charge / # of protons

Information: Nuclear reactions and ionizing radiation

A **nuclear reaction** is a change in the composition of the nucleus of an atom. This is not normally considered a chemical reaction, and does not depend on what molecule the atom might be in.

There are three types of nuclear reactions: fusion, fission, and radioactivity. Fusion (combining of nuclei into larger nuclei, such as in stars and the sun) and fission ("splitting the atom," such as in a nuclear reactor) do not concern us much in chemistry.

Some isotopes are radioactive, meaning that their nuclei break down ("decay") and give off particles, "rays," or both. There is no simple way to predict which isotopes are radioactive.

Table 1: Some types of ionizing radiation produced in nuclear reactions

Type of Radiation	Symbol	Mass Number	Charge	Relative penetrating ability	Shielding required	Biological hazard
Alpha particle	α, $^{4}_{2}He$	4	2+	very low	clothing	none unless inhaled
Beta particle	β, $^{0}_{-1}e$	0	1–	low	heavy cloth, plastic	mainly to eyes, skin
Gamma ray	γ, $^{0}_{0}\gamma$	0	0	very high	lead or concrete	whole body
Neutron	$^{1}_{0}n$	1	0	very high	water, lead	whole body
Positron	β^{+}, $^{0}_{1}e$	0	1+	low	heavy cloth, plastic	mainly to eyes, skin

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Critical Thinking Questions:

6. What does the subscript indicate in the **symbols** in Table 1?

Charge

7. Explain how your answer to CTQ 6 is consistent with your answer to CTQ 5.

it is the same

8. Consider the following nuclear reaction: $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$

   a. What type of radiation is produced? alpha particle

   b. How does the number of protons in the reactant compare with the total number of protons in the products?

   it is the same

   c. How does the number of neutrons in the reactant compare with the total number of neutrons in the products?

   it is the same

   d. How does the mass number of the reactant compare with the total of the mass numbers of the products?

   it is the same

   e. Show how each side of the reaction equation would change if a gamma ray were also released in the process.

   would not change, would just have a gamma particle

9. Balance the mass numbers and "atomic numbers" to complete the equation.

   a. $^{131}_{53}I \rightarrow ^{0}_{-1}e$ + $^{131}_{54}Xe$

   b. What type of radiation is given off in this reaction?

   beta particle

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Table 2: Half-lives of some radioisotopes

Radioisotope	Radiation type	Half-life	Use
barium-131	γ	11.6 days	detection of bone tumors
carbon-14	β	5730 yr	carbon dating
chromium-51	γ, X-rays	27.8 days	measuring blood volume
cobalt-60	β, γ	5.3 yr	food irradiation, cancer therapy
iodine-131	β	8.1 days	hyperthyroid treatment
uranium-238	α, β, γ	4.47×10^9 yr	dating igneous rocks

The time required for half of a sample of a radioactive isotopes to decay is called the half-life ($t_{½}$).

Critical Thinking Questions:

10. Consider a 100-gram sample of radioactive cobalt-60.
    a. How much time will it take before half the sample has decayed?

    5.3 yr

    b. Approximately how many grams of radioactive cobalt-60 will remain after 11 years?

    11/5.3 = 2   100 → 50 → 25g

11. Consider a sample of iodine-131.
    a. How many half-lives would it take for the sample to decay until less than 1% of the original isotope remained?

    100 → 50 → 25 → 12.5 → 6.25 → 3.125 → 1.56 → .78

    7 half-lives

    b. How many days would this be?

    7 x 8.1 days = 56.7 days

12. Considering only the half lives of uranium-238 and iodine-131, which would be more appropriate for internal usage (ingestion) for medical tests? Explain.

    Iodine-131 → decays faster

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Exercises:

1. After an organism dies, it stops taking in radioactive carbon-14 from the environment. If the carbon-14:carbon-12 ratio ($^{14}_{6}C/^{12}_{6}C$) in a piece of petrified wood is one sixteenth of the ratio in living matter, how old is the rock? (Hint: How many half lives have elapsed?)

   1/16 → 1/8 → 1/4 → 1/2 → 1

   4 half-lifes × 5730 = 22920 years

2. Would chromium-51 be useful for dating rocks containing chromium? Why or why not?

   No b/c will always contain chromium

3. Suppose that 0.50 grams of barium-131 are administered orally to a patient. Approximately how many milligrams of the barium would still be radioactive two months later?

   60 days / 11.6 days = 5 cycles

   .50 → .25 → .125 → .0625 → .03125 → .0156 mg

4. Complete the equations.

   a. $^{30}_{15}P \longrightarrow ^{0}_{1}e + ^{30}_{14}Si$ (What type of radiation is this? fission)

   b. $^{113}_{47}Ag \xrightarrow{\text{beta decay}} ^{0}_{-1}e + ^{113}_{48}Cd$

   c. $^{226}_{88}Ra \xrightarrow{\alpha \text{ and } \gamma \text{ emission}} ^{222}_{86}Rn + ^{4}_{2}He + ^{0}_{0}\gamma$

5. Read the assigned pages in your textbook and work the assigned problems.

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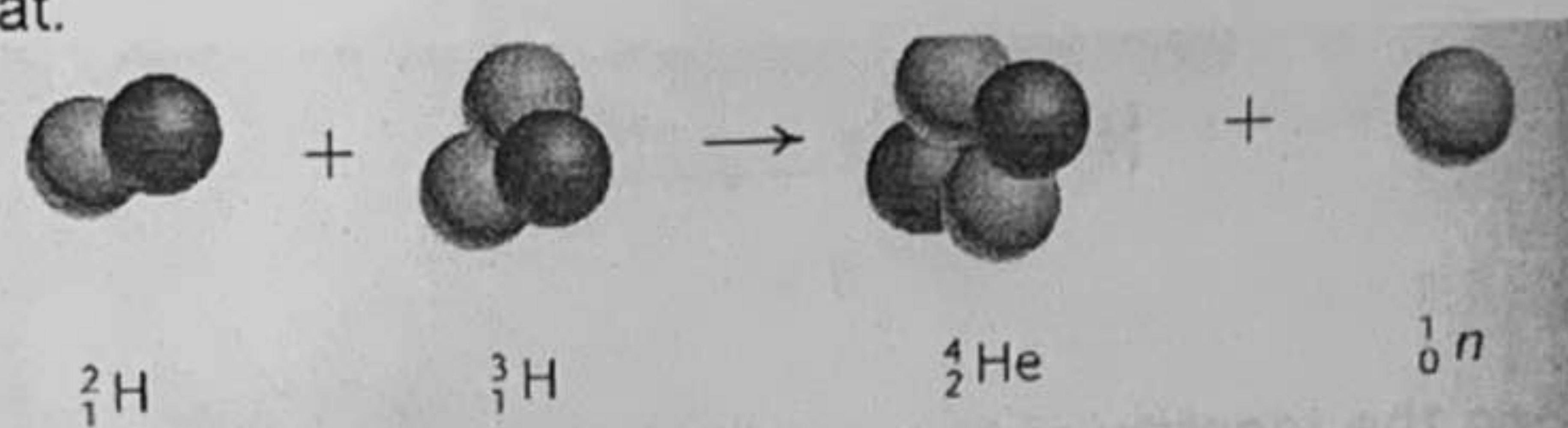
2. Fusion

Fusion occurs when 2 nuclei join together to form a larger nucleus. Fusion is brought about by bringing together two or more small nuclei under conditions of tremendous pressure and heat.



(Phillips, Strozak, Wistrom, Glencoe Chemistry. 2002 p. 766)

The following equations represent fusion reactions, where p = proton.

$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{1}H + ^{1}_{1}p$

$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$

$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2^{1}_{1}H$

Key Questions

1. What is fission?

   the breaking down of a nucle~~les~~s

2. What is fusion?

   the combining of 2 nucle i

3. What is the difference between deuterium, $^{2}_{1}H$ and tritium, $^{3}_{1}H$?

   one neutron

4. What two quantities are **conserved** in all natural nuclear transmutation?

   mass + charge

5. The fusion equations show the production of atoms of several different elements through the combination of hydrogen nuclei. These reactions require tremendous amounts of energy and pressure in order to be successful. Why is it so difficult to get two ***nuclei*** of elements to come together? (Hint: Think about the particles contained in the nucleus of all atoms)

   ~~Beau~~ Because they are all positive and repel eachother

6. The nuclei of atom twos will repel because of the like charges. Explain, in terms of nuclear charge, why fusion is only possible for the nuclei of small elements such as hydrogen and is impossible for the nuclei of large elements, such as uranium.

   less charge to repel

Exercises

1. An equation in the model shows the fusion of two deuterium nuclei to form a nucleus of tritium. Suggest another product that might form in this reaction.

$${}^{2}_{1}H + {}^{2}_{1}H \rightarrow$$ ${}^{4}_{2}He$

2. Describe *how* to find the identity of the species X in the equation.

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{152}_{60}Nd + \underline{X} + 3{}^{1}_{0}n$$

${}^{81}_{32}Ge$

mass + charge need to be equal on both sides of the reaction

3. What is missing in the following reaction?

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{55}Cs + {}^{90}_{37}Rb + 2{}^{1}_{0}n$$

4. An atom of U-235 absorbs a neutron and produces an atom of Sb-123, four neutrons and an unknown nuclide, X. Write the decay equation to represent this reaction and identify the other nuclide, X, formed in this reaction.

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{123}_{51}Sb + 4{}^{1}_{0}n + {}^{109}_{41}Nb$$

5. Classifying the following equations as fission or fusion.

	Fission or Fusion?
${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{1}p$	fusion
${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$	fission
${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{138}_{54}Xe + {}^{95}_{38}Sr + 3\,{}^{1}_{0}n$	fission
${}^{3}_{2}He + {}^{3}_{2}He \rightarrow {}^{4}_{2}He + 2{}^{1}_{1}H$	fusion

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HALF-LIFE PROBLEMS

Name______________________ Block ________

1. An isotope of cesium (cesium-137) has a half-life of 30 years. If 1.0 g of cesium-137 disintegrates over a period of 90 years, how many g of cesium-137 would remain?

HL: 30 years
decay length: 90 years
cycles: 3
starting amount: 1.0g
ending amount: X

$\frac{90}{30} = 3$ cycles

1 → .5 → .25 → .125g

2. Actinium-226 has a half-life of 29 hours. If 100 mg of actinium-226 disintegrates over a period of 58 hours, how many mg of actinium-226 will remain?

HL: 29 hours
decay length: 58 hours
cycles: 2
Starting amount: 100mg
ending amount: X

$\frac{58}{29} = 2$ cycles

100 → 50 → 25mg

3. Sodium-25 was to be used in an experiment, but it took 3.0 minutes to get the sodium from the reactor to the laboratory. If 5.0 mg of sodium-25 was removed from the reactor, how many mg of sodium-25 were placed in the reaction vessel 3.0 minutes later if the half-life of sodium-25 is 60 seconds?

HL: 60 seconds
decay length: 3 minutes → 180 seconds
Cycles: 3
Starting amount: 5.0mg
ending amount: X

$\frac{180 sec}{60 sec} = 3$

5.0 → 2.5 → 1.25 → .75 mg

4. The half-life of isotope X is 2.0 years. How many years would it take for a 4.0 mg sample of X to decay and have only 0.50 mg of it remain?

HL: 2.0 years
decay length: X
cycles:
starting amount: 4.0mg
ending amount: 0.50mg

4 →(1) 2 →(2) 1 →(3) .5

$\frac{X}{2} = 3$ cycles

6 years

5. Selenium-83 has a half-life of 25.0 minutes. How many minutes would it take for a 10.0 mg sample to decay and have only 1.25 mg of it remain?

HL: 25min
decay length: X
cycles:
starting amount: 10.0mg
ending amount: 1.25

10 →(1) 5 →(2) 2.5 →(3) 1.25

$\frac{X}{25 min} = 3$

75min

6. The half-life of Po-218 is three minutes. How much of a 2.0 gram sample remains after 15 minutes? ~~Suppose you wanted to buy some of this isotope, and it required half an hour for it reach you. How much should you order if you need to use 0.10 gram of this material?~~

HL: 3min
decay length: 15min
cycles: 5
Starting amount: 2.0g
ending amount: X

$\frac{15 min}{3 min} = 5$ cycles

2 → 1 → .5 → .25 → .125 → .0625g

Honors Chemistry: Unit 2 Test Review
Atomic Structure & Nuclear Chemistry

1. Define the following terms:

Radiation:

radioactive decay: look these up in notes + packet

transmutation:

nuclear reaction:

2. How are mass number and the atomic number affected by the loss of a:

a. beta particle - does not alter mass, atomic # increases by 1

b. alpha particle - mass is decreased by 4, atomic # is decreased by 2

c. gamma ray - does not alter mass or atomic #

3. What is the difference between bombardment and emission?

Bombardment → two nuclear particles hitting into each other (fusion)

emission → giving off a nuclear particle (ex. alpha decay)

4. What causes atoms to be radioactive?

unstable nuclei

5. What are the three most common types of radiation? What is the symbol, mass, charge, and penetrating power of each?

		mass	charge	power	protectors
alpha	$^{4}_{2}He$	4	+2	low	air / paper
beta	$^{0}_{-1}e$	0	-1	medium	foil, wood
gamma	$^{0}_{0}\gamma$	0	0	high	lead, concrete

6. How are nuclear fission and fusion different?

→ fission is a larger nuclei breaking down to smaller nuclei

→ fusion is multiple nuclei combining into more massive nuclei

~~t are the transuranium elements? What is significant about them?~~

hat is half-life? What does it measure?

↳ the amount of time it takes for half of an ~~[illegible]~~ unstable isotope to decay to a stable isotope

→ use it to date how old materials are

What do half-life graphs typically look like?

. What are some uses of nuclear chemistry?

- nuclear power
- nuclear bombs (warfare)

Nuclear Equations: Fill in the blanks with the appropriate answer.

11. $^{231}_{91}Pa \rightarrow ^{4}_{2}He +$ $\underline{^{227}_{89}Ac}$

12. $^{210}_{84}Po \rightarrow ^{0}_{-1}e +$ $\underline{^{210}_{85}At}$

13. $^{233}_{90}Th \rightarrow$ $\underline{^{233}_{91}Pa}$ $+ ^{0}_{-1}e$

Write the nuclear equations:

14. Uranium-235 decomposes naturally. As a result it produces a new element and an alpha particle.

$$^{235}_{92}U \rightarrow ^{4}_{2}He + ^{231}_{90}Th$$

15. Europium-152 undergoes beta decay.

$$^{152}_{63}Eu \rightarrow ^{0}_{-1}e + ^{152}_{64}Gd$$

16. Holmium-165 undergoes alpha bombardment.

$$^{165}_{67}Ho + ^{4}_{2}He \rightarrow ^{169}_{69}Tm$$

17. Einsteinium captures an electron.

$$^{252}_{99}Es + ^{0}_{-1}e \rightarrow ^{252}_{98}Cf$$

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Half-Life Problems:

18. Rh-111 has a half-life of 25.0 minutes. You have a sample of Rh-111 ...
Rh-111 undergoes alpha decay.

a. Write the balanced nuclear equation.

$^{111}_{45}Rh \rightarrow ^{4}_{2}He + ^{107}_{43}Tc$

b. How many grams of Rh-111 will remain after 200.0 min have passed?

$\frac{200.0 min}{25.0 min} = 8$ cycles

150 → 75 → 37.5 → 18.75 → 9.375 →
4.6875 → 2.34375 → 1.1719 → 0.586g

19. A sample of a radioactive isotope has a half-life of 14.6 days. If your sample has a mass of 4.75g, how much would remain after 82.4 days?

$\frac{82.4 days}{14.6 days} \approx 6$

4.75g → 2.38 → 1.19 → 0.595 →
0.2975 → 0.14875 → 0.0248g

20. The half life of Cs-137 is 30.2 years. If the initial mass of the sample is 1.00kg, how much will remain after 151 years?

$\frac{151}{30.2} = 5$

1 → .5 → .25 → .125 → .0625 → 0.03125kg

21. Carbon-14 has a half life of 5730 years. Consider a sample of fossilized wood that when alive would have contained 24g of C-14. It now contains 1.5g. How old is the sample?

24 →(1) 12 →(2) 6 →(3) 3 →(4) 1.5

4 cycles × 5730 years = 22920 years

A 64g sample of Germanium-66 is left undisturbed for 12.5 hours. At the end of that period, only 2.0g remain. What is the half-life of this material?

64 →(1) 32 →(2) 16 →(3) 8 →(4) 4 →(5) 2

5 cycles = $\frac{12.5}{\text{Half-life}}$ → $\frac{12.5}{5}$ = 2.5 hours

Atomic Structure

ISOTOPIC SYMBOL	NUMBER OF PROTONS	NUMBER OF ELECTRONS	NUMBER OF NEUTRONS	ATOM OR ION?	NET CHARGE
$^{131}_{35}Br^{1-}$	35	36	96	Ion	-1
$^{79}_{34}Se^{-2}$	34	36	45	Ion	-2
$^{22}_{10}Ne$	10	10	12	Atom	0
$^{11}_{5}B^{3+}$	5	2	6	Ion	+3

Define:

mass number protons + neutrons.

atomic number # of protons

ion charged particle → # of protons + electrons are not equal

isotope two atoms that have the same # of protons, but different # of neutrons

Where are each of the following located?

Protons nucleus

Neutrons nucleus

Electrons electron cloud

Nucleus center of atom

Energy levels around the nucleus

Average Atomic Mass

1. An element X has three isotopes: X-26, X-28, X-29. Calculate the average atomic mass of element X if X-26 has a mass of 25.998 amu and is 20.33% abundant, X-28 has a mass of 28.003 amu and is 5.99% abundant, and X-29 has a mass of 28.986 amu and is 73.68% abundant.

$$\frac{(25.998 \times 20.33) + (28.003 \times 5.99) + (28.986 \times 73.68)}{100} = 28.32 \text{ amu}$$

Silicom ←

2. Oxygen has three naturally occurring isotopes: O-16 (15.995 amu; 99.762%), O-17 (16.999 amu; 0.038%), and O-18 (17.999 amu; 0.200%). Calculate the average atomic mass of oxygen.

$$\frac{(15.995 \times 99.762) + (16.999 \times .038) + (17.999 \times .200)}{100} = 15.99 \text{ amu}$$

↓ 16 amu

3. If naturally occurring boron is 80.20% B-11 (atomic mass = 11.009 amu) and 19.80 % of some other isotopic form of boron, what must the atomic mass of this second isotope be in order to account for the 10.811 amu average atomic mass of boron? (Express to 3 decimal places)

$$10.811 \text{ amu} = \frac{(80.20 \times 11.009) + (19.80 \times X)}{100}$$

$$1081.1 = 882.92 + 19.80X$$

$$-882.92 \quad -882.92$$

$$\frac{198.1782}{19.80} = \frac{19.80X}{19.80}$$

$$10.009 \text{ amu} = X$$