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
Atomic Symbol
Atomic Number

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Subatomic Particles

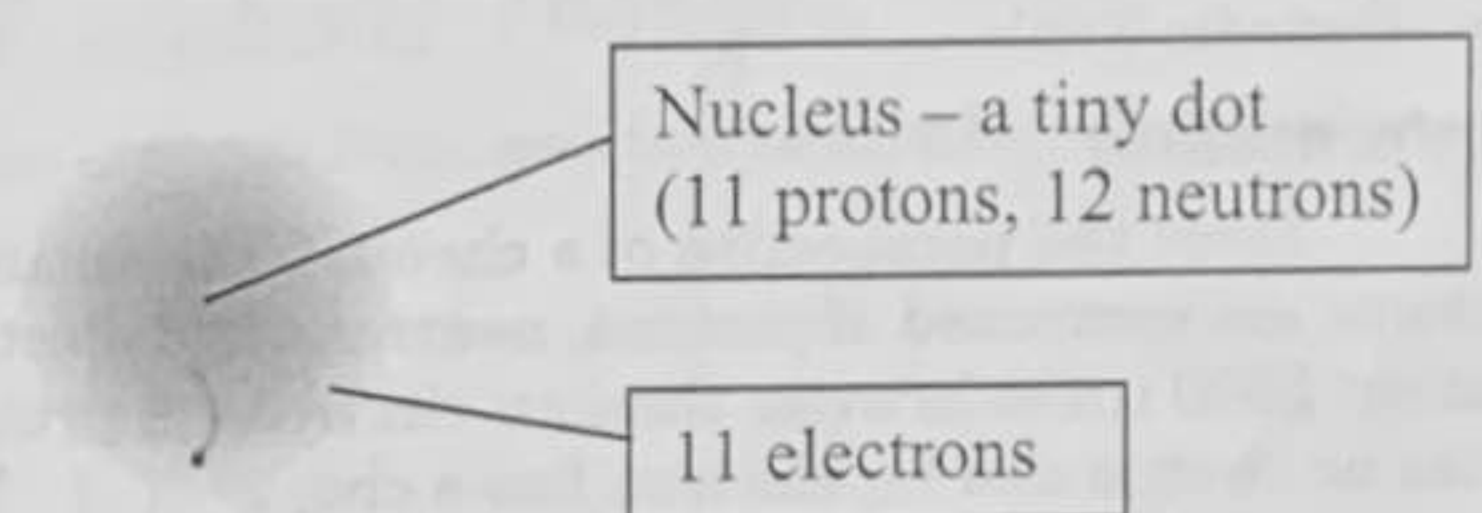
Particle	Symbol	Relative Charge	Absolute Mass	Relative Mass
electron	e^-	-1	9.109×10^{-31} kg	0
proton	p^+	+1	1.673×10^{-27} kg	1
neutron	n^0	0	1.675×10^{-27} kg	1

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.]

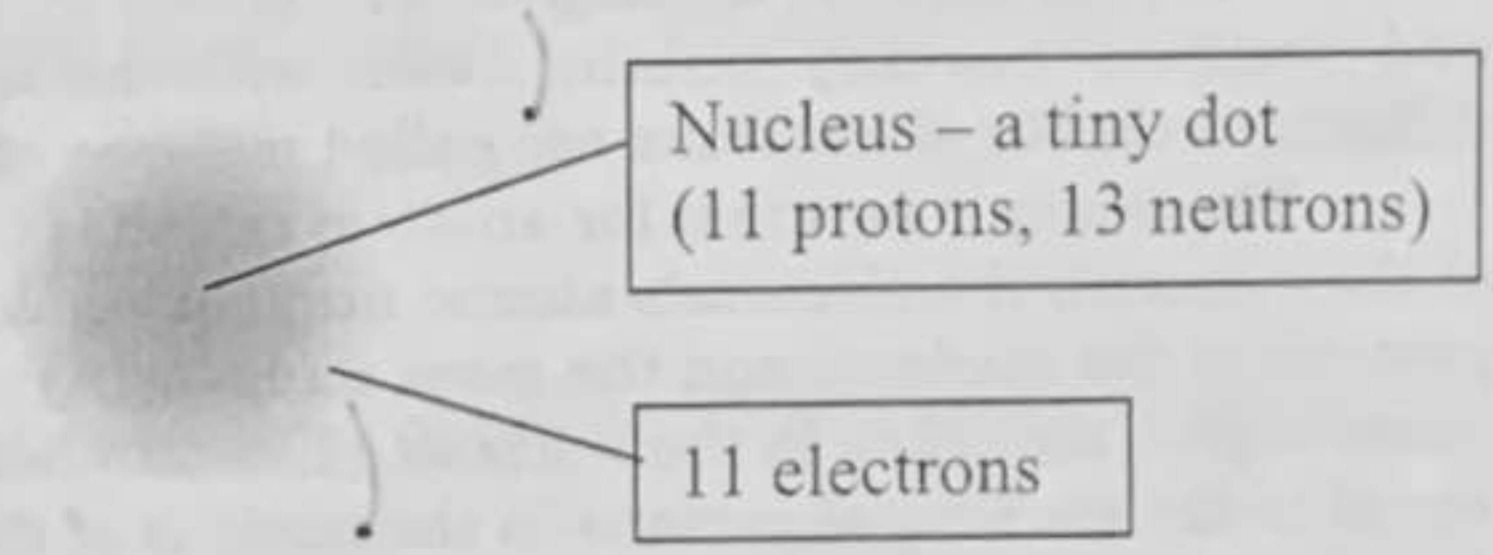
Isotope 1

$^{23}_{11}Na$



Isotope 2

$^{24}_{11}Na$



Key Questions

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

atomic # → # of protons

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

mass # → protons + neutrons

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

they are the same → this is for Neutral atoms

4. 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?

the nucleus

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

Same atomic number, same # of protons

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

mass # b/c # of neutrons changed

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 $^{37}_{17}Cl$.

# of protons and symbol and # of electrons

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

mass # and # 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	Mass Number A	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	92	$^{238}_{92}U$	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?

$$\frac{100\text{ pm}}{} \cdot \frac{1\text{ m}}{1\times10^{12}\text{ pm}} \cdot \frac{1\times10^{15}\text{ fm}}{1\text{ m}} = 100000\text{ fm} = 100\text{ pm}$$

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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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

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Name: ______________________________ 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

Name: ______________________ Date: __________

Isotopes Practice

Calculating atomic number, mass number, subatomic particles.

PART A

Given the following isotopes, determine the atomic number, the mass number, the number of protons, electrons and neutrons.

Isotope Symbol	Atomic Number	Mass Number	Protons	Electrons	Neutrons	Isotope Name
$^{131}_{53}I$	53	131	53	53	78	Iodine - 131
$^{35}_{16}S$	16	35	16	16	19	Sulfur - 35
$^{4}_{2}He$	2	4	2	2	2	Helium - 4
$^{27}_{13}Al$	13	27	13	13	14	Aluminum - 27
$^{81}_{36}Kr$	36	81	36	36	45	Krypton - 81
$^{81}_{37}Rb$	37	81	37	37	44	Rubidium - 81

PART B

Complete the following chart by writing the symbol for the isotope of the following elements. In addition, give the number of protons, electrons, mass number and atomic number and complete the element name.

Element Name	Neutrons	Protons	Electrons	Mass Number	Atomic Number	Isotope Symbol
Uranium-237	145	92	92	237	92	$^{237}_{92}U$
Chlorine-45	28	17	17	45	17	$^{45}_{17}Cl$
Oxygen-17	9	8	8	17	8	$^{17}_{8}O$
Boron-11	6	5	5	11	5	$^{11}_{5}B$
Beryllium-9	5	4	4	9	4	$^{9}_{4}Be$
Hydrogen-2	1	1	1	2	1	$^{2}_{1}H$
Carbon-14	8	6	6	14	6	$^{14}_{6}C$

Adapted from MVCSP

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

Name:
Date:

Bohr Model and Valence Electron Worksheet

Label the missing pieces of each given element's periodic square. Give its number of protons (P), neutrons (N), and electrons (E). Draw the Bohr digrams for each element as well. ~~Only draw Lewis structures if you think you know how – they are not required.~~

B — 5, Boron, 10.81
P = 5
N = 6
E = 5
Bohr Diagram


~~Lewis Structure B~~

Li — 3, Lithium, 6.941
P = 3
N = 4
E = 3
Bohr Diagram

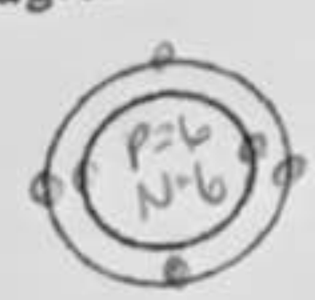

~~Lewis Structure Li~~

Ne — 10, Neon, 20.18
P = 10
N = 10
E = 10
Bohr Diagram

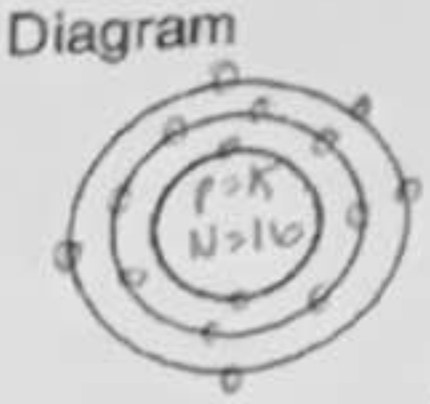

~~Lewis Structure Ne~~

He — 2, Helium, 4.003
P = 2
N = 2
E = 2
Bohr Diagram

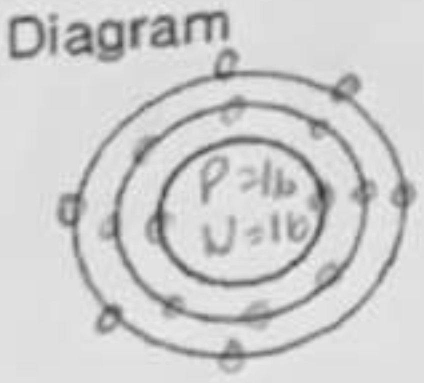

~~Lewis Structure He~~

C — 6, Carbon, 12.01
P = 6
N = 6
E = 6
Bohr Diagram


~~Lewis Structure C~~

P — 15, Phosphorus, 30.97
P = 15
N = 16
E = 15
Bohr Diagram


~~Lewis Structure P~~

S — 16, Sulfur, 32.07
P = 16
N = 16
E = 16
Bohr Diagram


~~Lewis Structure S~~

Mg — 12, Magnesium, 24.31
P = 12
N = 12
E = 12
Bohr Diagram


~~Lewis Structure Mg~~

H — 1, hydrogen, 1.008
P = 1
N = 0
E = 1
Bohr Diagram


~~Lewis Structure H~~

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Average Atomic Mass Classwork

1. Answer the following questions using the data below:

Isotope	Mass (amu)	% Abundance
1	31.972	95.0
2	32.971	0.76
3	33.967	4.22
4	35.967	0.014

a. What is the most common isotope of the unknown element?

Isotope 1

b. Calculate the average atomic mass of the unknown element.

$(.95 \times 31.972) + (0.0076 \times 32.971) + (.0422 \times 33.967) +$
$(.00014 \times 35.967)$
$= 32.062$ amu

c. Use your periodic table to identify the unknown element.

Sulfur

d. What is the atomic number of this element? 16

e. This atom forms an ion with a charge of –2. Write the isotopic symbol for the most common isotope of this element.

$^{32}_{16}S^{-2}$

2. Copper has two naturally occurring isotopes with mass numbers 63 and 65. The relative abundances and atomic masses of these isotopes are as follows: 69.2% for mass= 62.93 amu and 30.8% for mass=64.93amu. Calculate the average atomic mass for copper.

$(.692 \times 62.93) + (.308 \times 64.93)$
$= 63.55$ amu

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3. Samples of an unknown element X were collected and their masses were recorded. Use the information presented in the data table to answer the following questions:

Isotope	Mass(amu)	% Abundance
1	37.765	9.67
2	39.056	78.68
3	40.003	11.34
4	41.060	0.31

a. Determine the mass number for each isotope of element X.

1 → 38   4 → 41
2 → 39
3 → 40

b. What is the most common isotope of element X?

39 X (isotope #2)

c. Calculate the average atomic mass of elements X.

(.0967 × 37.765) + (.7868 × 39.056) + (.1134 × 40.003) + (.0031 × 41.060)

= 39.045 amu

d. Use your periodic table to identify element X.

K

e. What is the atomic number of this element?

19

f. This atom forms an ion with a charge of 1+. Write the isotopic symbol for the most common isotope of this element.

$^{39}_{19}K^{+1}$

Average Atomic Mass CW

1. 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%)

$(35.968 \times .00337) + (37.963 \times .00063) + (39.962 \times .99600)$

$= 39.947$ 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?

$10.811 = (11.009 \times .8020) + (x \times .1980)$

$1.982 = x \cdot .1980$

$x = 10.009$ 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.

$(25.998 \times .2033) + (28.003 \times .0599) + (28.986 \times .7368)$

$= 28.320$ 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.

$(15.995 \times .99762) + (16.999 \times .00038) + (17.999 \times .00200)$

$= 15.999$ 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 x .075) + (7.016 x .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 x .7578) + (36.966 x .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 x .7899) + (24.986 x .10000) + (25.983 x .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 y = 1 - X

^{63}Cu = 68.97%

65 = 31.03%

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

63.55 = 62.930x - 64.928x + 64.928

-64.928 -64.928

-1.378 = 62.930x - 64.928x

-1.378 = -1.998 x

0.6897 = x

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Nuclear Equations Notes

- Nuclear chemistry is the study of how unstable nuclei (nucleus of the atom) interact with each other.
- Two main types
  1. Fusion - when two nuclear particles (nuclei) become one

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

     → only occurs in the sun

     * requires ALOT of energy and produces a lot of energy
  2. Fission - when a nuclei decays down into multiple nuclei

     ex. $^{3}_{1}H \rightarrow ^{0}_{-1}e + ^{3}_{2}He$

     → occurs on earth in nuclear reactors to create nuclear energy

     * issue with it, left over radioactive materials are hazardous

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 nucleus is involved. Electrons are ignored. Some atomic nuclei are inherently unstable and spontaneously change or "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 by paper
Beta- e- emission	β- electron	-1	0	increase by 1	0	Aluminum Foil
Beta+ e- capture	β+ Positron	+1	0	decrease by 1	0	Aluminum Foil
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 nature 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 in 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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Balancing Nuclear Reactions Practice

1. $^{222}_{86}Rn$ ---------> $^{118}_{84}Po$ + $^{4}_{2}He$

2. $^{238}_{92}U$ ---------> $^{234}_{90}Th$ + $^{4}_{2}He$

3. $^{234}_{90}Th$ ---------> $^{226}_{88}Ra$ + $^{4}_{2}He$

4. $^{214}_{82}Pb$ ---------> $^{214}_{83}Bi$ + $^{0}_{-1}e$

5. $^{234}_{92}U$ ---------> $^{234}_{93}Np$ + $^{0}_{-1}e$

6. Write a balanced nuclear equation for the Beta decay of:
   a. Nitrogen-16 $^{16}_{7}N \rightarrow ^{0}_{-1}e + ^{16}_{8}O$
   b. Potassium-40 $^{40}_{19}K \rightarrow ^{0}_{-1}e + ^{40}_{20}Ca$

7. Write a balanced nuclear equation for the Alpha decay of:
   a. Plutonium-244 $^{244}_{94}Pu \rightarrow ^{4}_{2}He + ^{240}_{92}U$
   b. Strontium-90 $^{90}_{38}Sr \rightarrow ^{4}_{2}He + ^{86}_{36}Kr$

8. Write the balanced nuclear equations for the Beta, Alpha, and Gamma decay of Radium-226.
   $^{226}_{88}Ra \rightarrow ^{0}_{-1}e + ^{226}_{89}Ac$ | $^{226}_{88}Ra \rightarrow ^{4}_{2}He + ^{222}_{86}Rn$ | $^{226}_{88}Ra \rightarrow ^{226}_{88}Ra +$ [illegible]

9. How are the mass number and atomic number of the nucleus affected by the loss of the following?
   a. beta particle mass# stays the same, A# increase by 1
   b. alpha particle mass # decreases by 4, A# decreases by 2
   c. gamma particle mass # stays the same, atomic # stays the same

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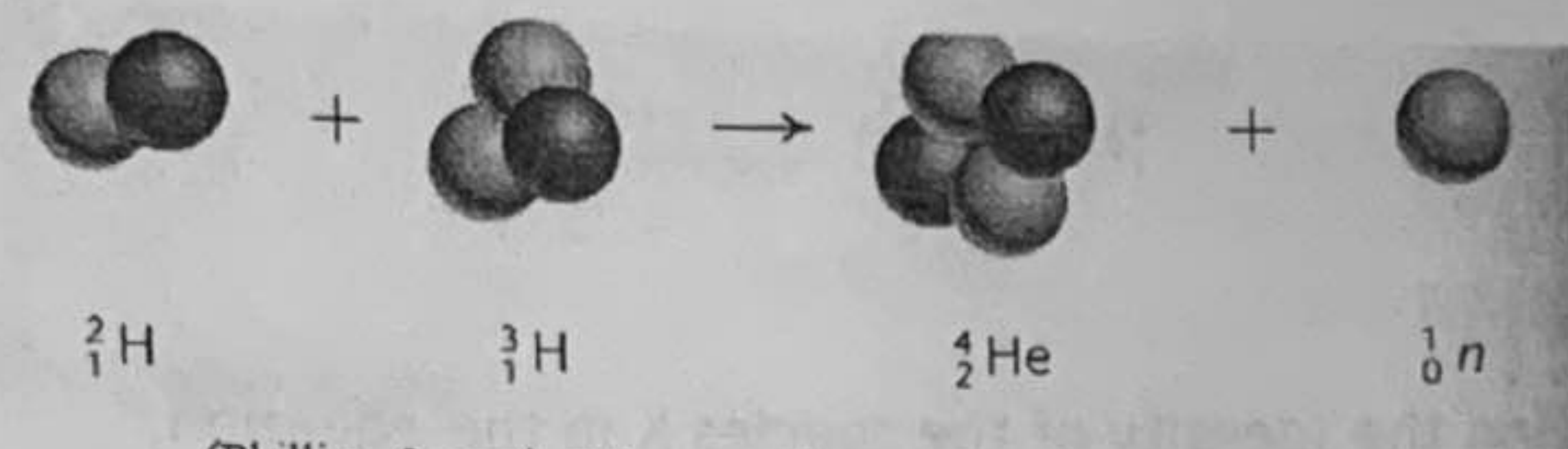
2. Fusion

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 nucleus

2. What is fusion?

   the combining of 2 nuclei

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)

   ~~Beca~~ 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

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...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.

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

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?

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

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

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 →(1) 25 →(2) 12.5 →(3) 6.25 g

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 →(1) 100 →(2) 50 →(3) 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 →(1) 2 →(2) 1

5730 x 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 → 6.25 g

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

Notes: Half-Life

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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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: 25 min
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: 3 min
decay length: ~~[illegible]~~ 15 min
cycles: 5
Starting amount: 2.0g
ending amount: X

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

2 → 1 → .5 → .25 → .125 → .0625g

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