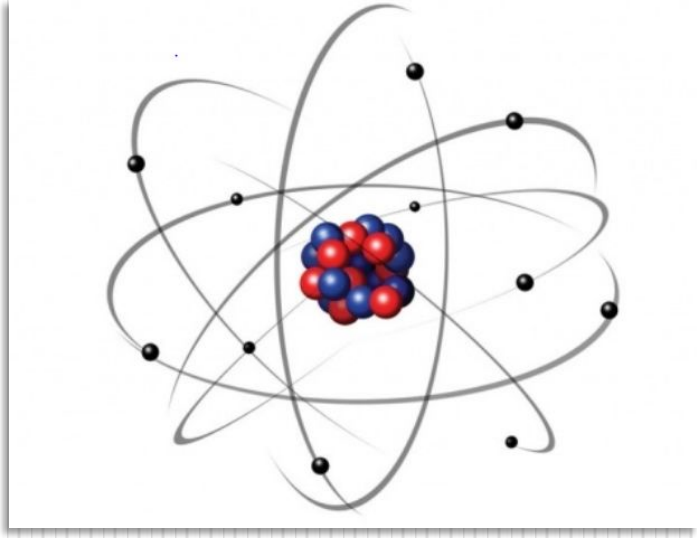
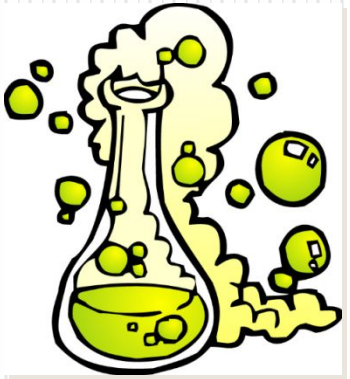
Atomic number, Mass number and Isotopes



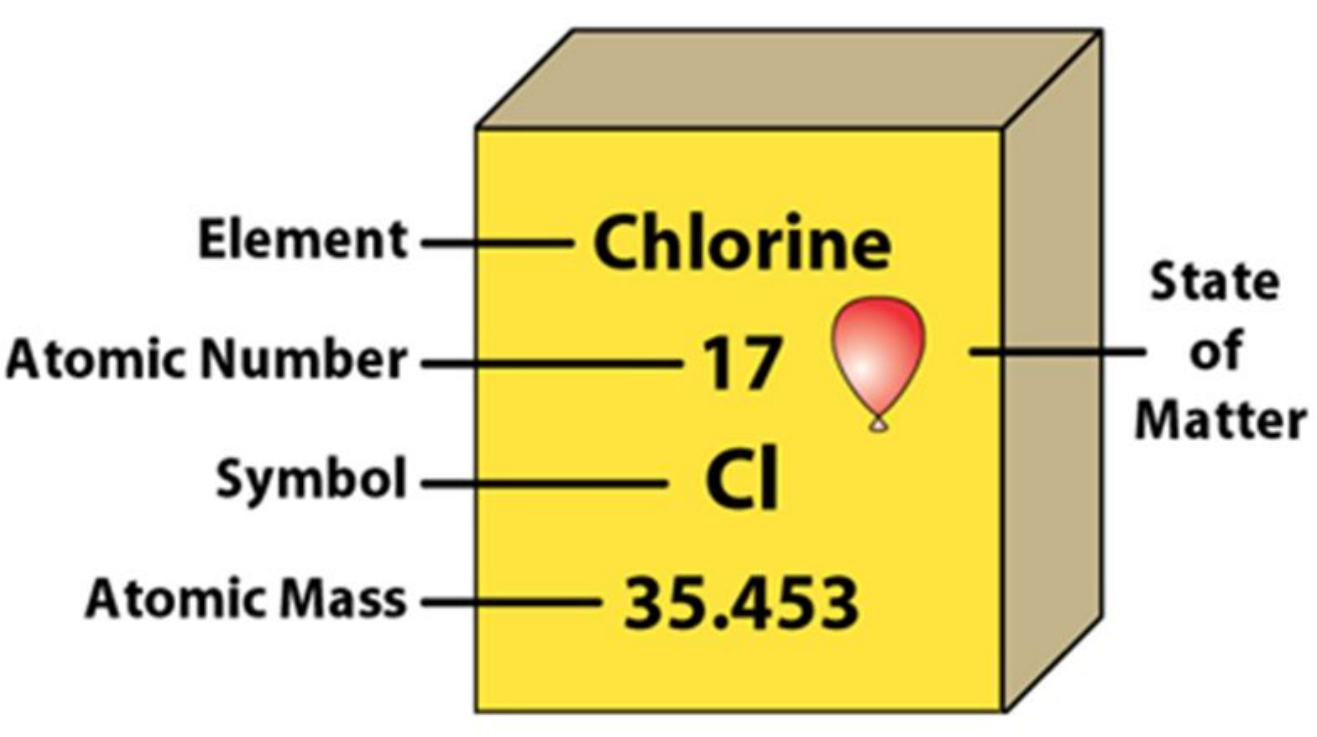


Periodic Table

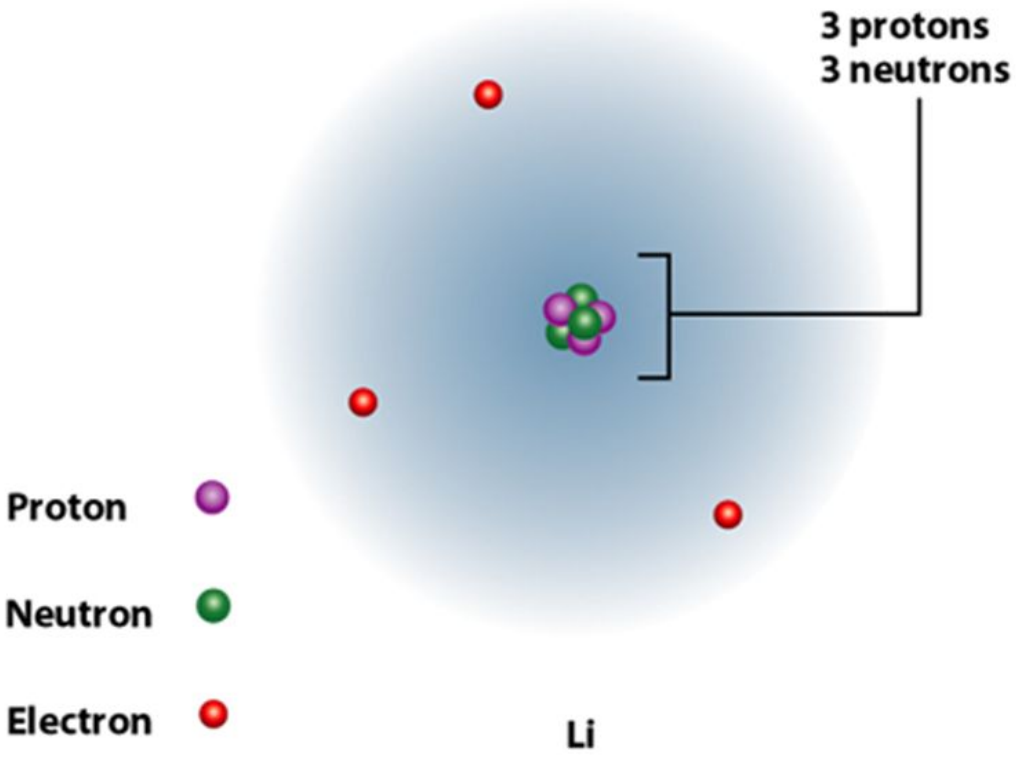
Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1	1 H 1.008																	2 He 4.0026
2	3 Li 6.94	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
3	11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.085	15 P 30.974	16 S 32.06	17 Cl 35.45	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.63	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.96	43 Tc [97.91]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	* 71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At [209.99]	86 Rn [222.02]
7	87 Fr [223.02]	88 Ra [226.03]	** 103 Lr [262.11]	104 Rf [265.12]	105 Db [268.13]	106 Sg [271.13]	107 Bh [270]	108 Hs [277.15]	109 Mt [276.15]	110 Ds [281.16]	111 Rg [280.16]	112 Cn [285.17]	113 Uut [284.18]	114 Fl [289.19]	115 Uup [288.19]	116 Lv [293]	117 Uus [294]	118 Uuo [294]

*Lanthanoids	*	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [144.91]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05
**Actinoids	**	89 Ac [227.03]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237.05]	94 Pu [244.06]	95 Am [243.06]	96 Cm [247.07]	97 Bk [247.07]	98 Cf [251.08]	99 Es [252.08]	100 Fm [257.10]	101 Md [258.10]	102 No [259.10]

Information about an element



- Let’s take Li atom for an example:

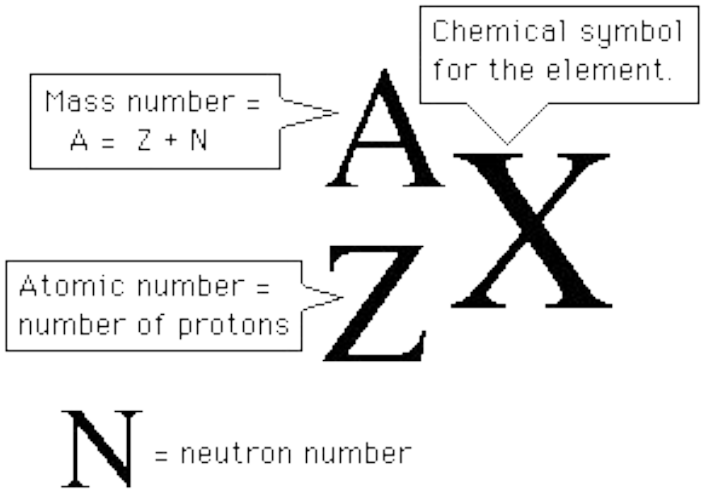


It has 3 protons, 3 neutrons and 3 electrons.
What are its atomic number and mass number?

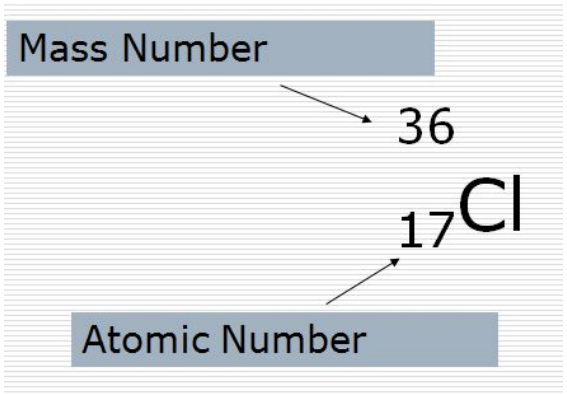
Atomic number and Mass Number

- The **number of protons** in a given atom is called the ***atomic number***, or the proton number, ***Z***.
- The **number of electrons** in the atom is also **equal to *Z*** because the atom is **electrically neutral**.
- The **total number of protons and neutrons** in an atom is called the ***mass number, A***.
- The **number of neutrons**, the ***neutron number***, is **A - Z**.
- An electron carries an atomic unit of negative charge, a proton carries an atomic unit of positive charge, and a neutron is electrically neutral.

Atomic number and Mass Number

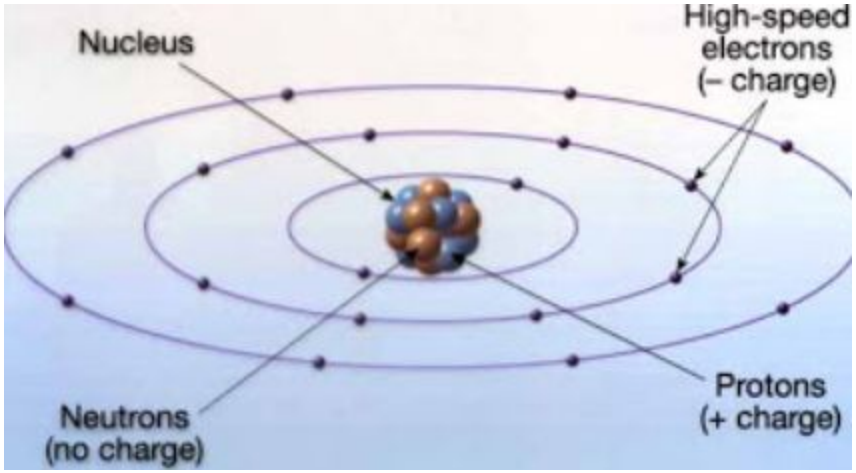


Example:



Atomic Number = 17
Mass Number = 36
Neutron number = 19

Number of electrons



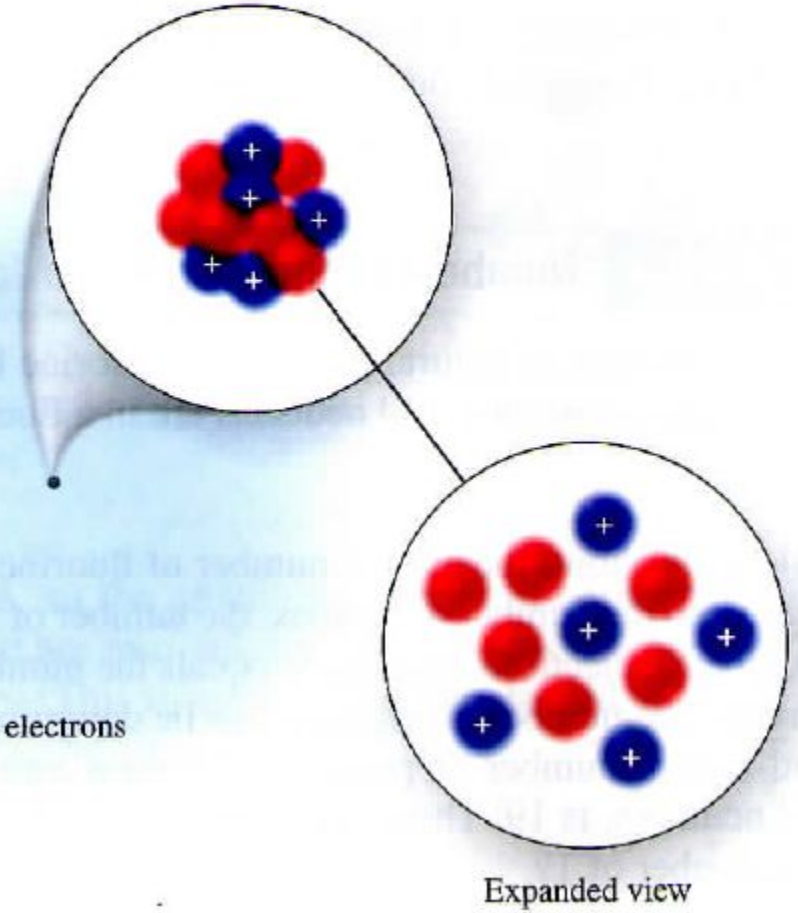
- An atom is neutral.
- The net charge is zero.
- Therefore, Number of protons = Number of electrons
- Atomic number = Number of electrons
- For chlorine (Cl),

  Atomic number = Number of electrons = 17

EXAMPLE 2.1 Determining Atomic Number and Mass Number

For the atom represented in the following diagram,

(a) Determine the number of protons and neutrons.
(b) Identify the atomic number and the element.
(c) Determine the mass number for this isotope.



Solution:

(a) The protons and neutrons make up the nucleus. The protons are positively charged and neutrons have no charge. There are five protons and six neutrons.

(b) The atomic number, the number of protons, is 5. From the periodic table we see that the element with atomic number 5 is boron.

(c) The mass number, the sum of the protons and neutrons, is 11.

Example 2.1

DCM, Worked Examples

Give the number of protons, neutrons, and electrons in each of the following species: (a) $^{17}_{8}O$, (b) $^{199}_{80}Hg$, and (c) $^{200}_{80}Hg$.

Example 2.1

DCM, Worked Examples

Give the number of protons, neutrons, and electrons in each of the following species: (a) $^{17}_{8}O$, (b) $^{199}_{80}Hg$, and (c) $^{200}_{80}Hg$.

Strategy Recall that the superscript denotes mass number and the subscript denotes atomic number. Mass number is always greater than atomic number. (The only exception is $^{1}_{1}H$, where the mass number is equal to the atomic number.)

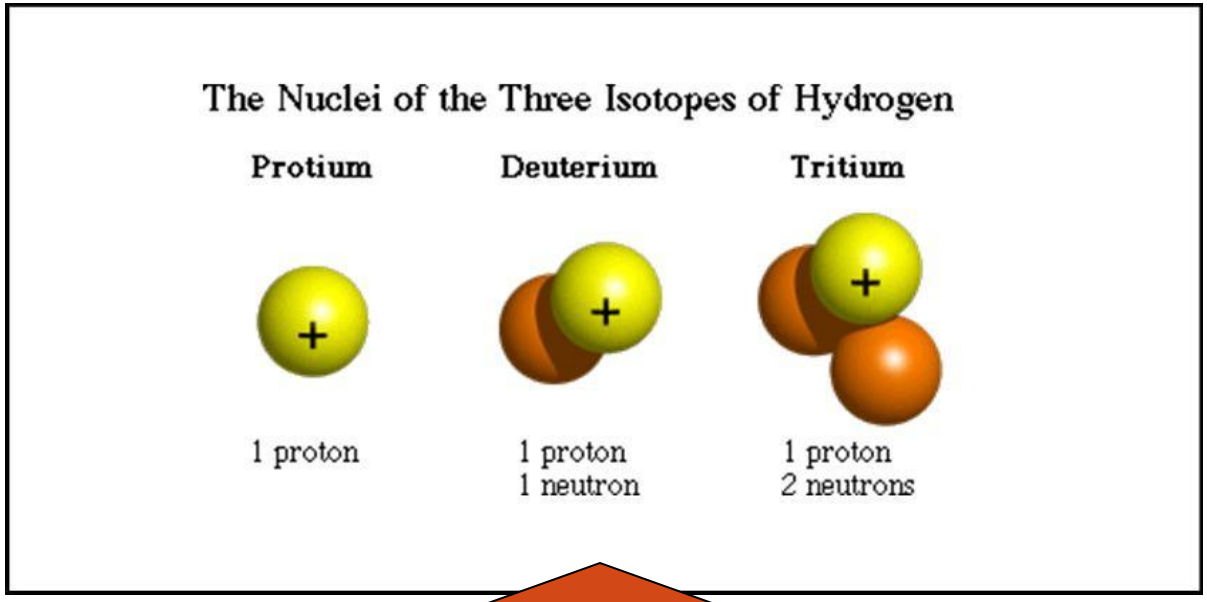
Solution

(a) The atomic number is 8, so there are 8 protons. The mass number is 17, so the number of neutrons is $17 - 8 = 9$. The number of electrons is the same as the number of protons, that is, 8.

Practice Exercise How many protons, neutrons, and electrons are in the following isotope of copper: $^{63}_{29}Cu$?

Isotopes同位素

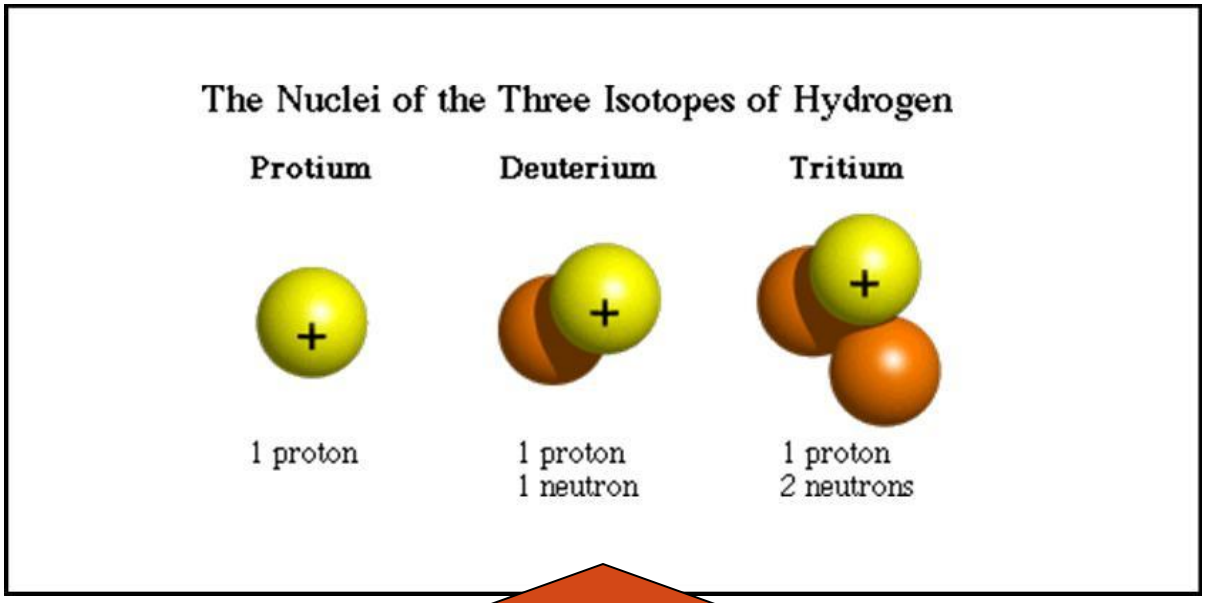
- They are atoms of the same element that have different numbers of ***neutrons.***
- Hydrogen has 3 **isotopes.**



Note how the number of protons never change!!!

Isotopes

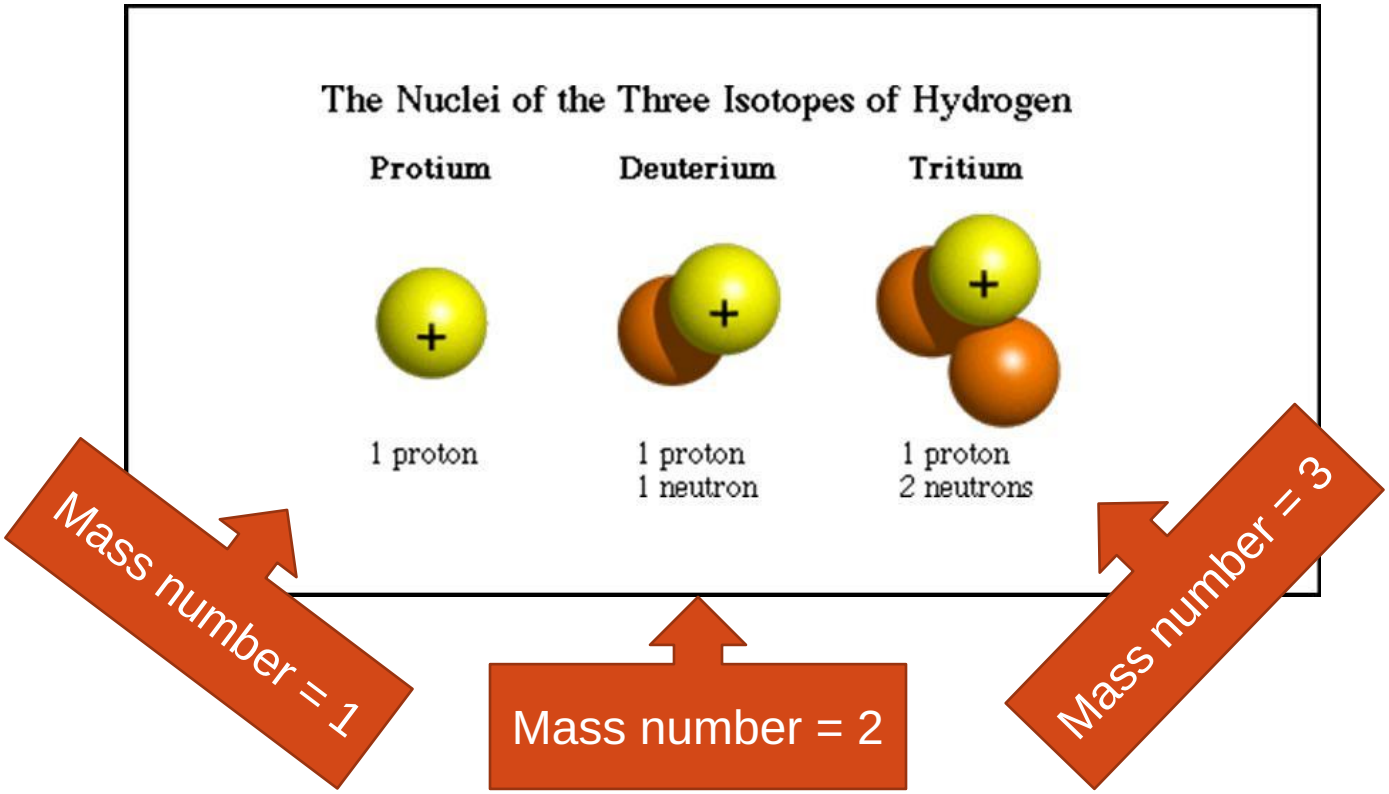
- Hydrogen has 3 **isotopes.**

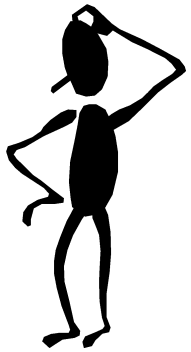


Have more neutrons, increases the mass.

Isotopes

- Hydrogen has 3 **isotopes.**





Do You Understand Isotopes?

How many protons, neutrons, and electrons are in $^{14}_{6}C$?

6 protons, **8 (14 - 6) neutrons**, 6 electrons

How many protons, neutrons, and electrons are in $^{11}_{6}C$?

6 protons, **5 (11 - 6) neutrons**, 6 electrons

EXAMPLE 2.2 Numbers of Subatomic Particles

The only stable isotope of naturally occurring fluorine has a mass number of 19. How many protons, electrons, and neutrons are in a fluorine atom?

Periodic Table

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1	1 H 1.008																	2 He 4.0026
2	3 Li 6.94	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
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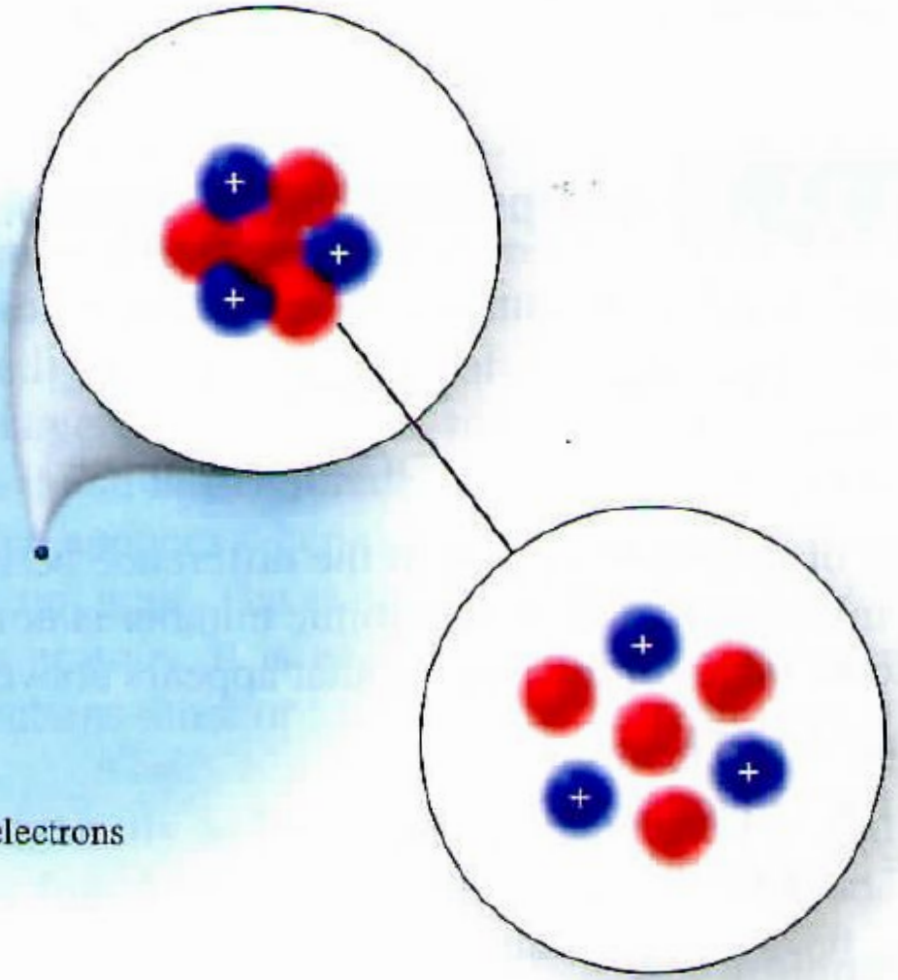
**Actinoids	**	89 Ac [227.03]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237.05]	94 Pu [244.06]	95 Am [243.06]	96 Cm [247.07]	97 Bk [247.07]	98 Cf [251.08]	99 Es [252.08]	100 Fm [257.10]	101 Md [258.10]	102 No [259.10]

Solution:

The periodic table shows the atomic number of fluorine is 9. Because the atomic number is equal to the number of protons, the number of protons in a fluorine atom is 9. The number of electrons in an atom equals the number of protons, so fluorine has 9 electrons. The number of neutrons can be determined from the known mass number and known number of protons. The mass number, the total number of protons and neutrons, is 19. There are 9 protons, so there must be 10 neutrons to give a mass number of 19.

EXAMPLE 2.3 Writing Isotope Symbols

Write two representations for the following isotope.



Solution:

There are three protons, so the atomic number is 3, corresponding to the element lithium (Li). There are four neutrons, so the mass number is 7, the sum of the protons and neutrons. This isotope can be represented as $^{7}_{3}Li$, ^{7}Li, lithium-7, or Li-7.

EXAMPLE 2.4 Interpreting Isotope Symbols

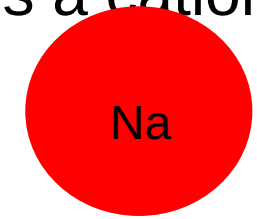
Determine the number of neutrons in each of the following isotopes.

(a) $^{238}_{92}U$ (b) ^{23}Na (c) hydrogen-3

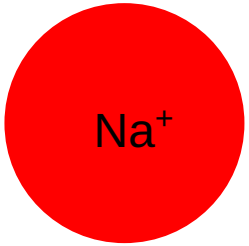
Cation and Anion

- An ***ion*** is an atom, or group of atoms, that has a net positive or negative charge.
- ***cation – ion with a positive charge***

If a neutral atom **loses one or more electrons** it becomes a cation.



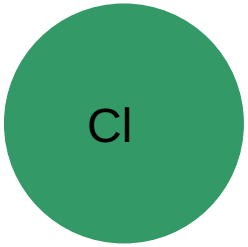
11 protons
11 electrons



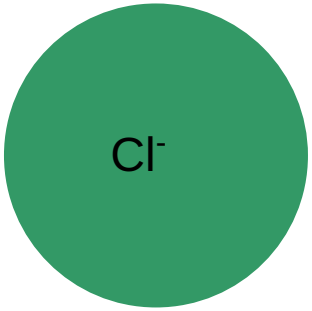
11 protons
10 electrons

- ***anion – ion with a negative charge***

If a neutral atom **gains one or more electrons** it becomes an anion.



17 protons
17 electrons



17 protons
18 electrons

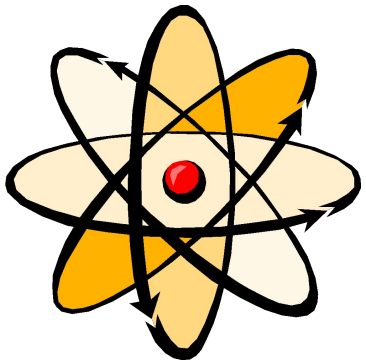
Cation and Anion

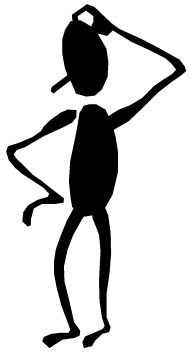
- A ***monatomic*** ***ion contains only one atom***

  eg. Na^{+}, Cl^{-}, Ca^{2+}, O^{2-}, Al^{3+}, N^{3-}

- A ***polyatomic*** ***ion contains more than one atom***

  eg. OH^{-}, CN^{-}, NH^{4+}, NO^{3-}





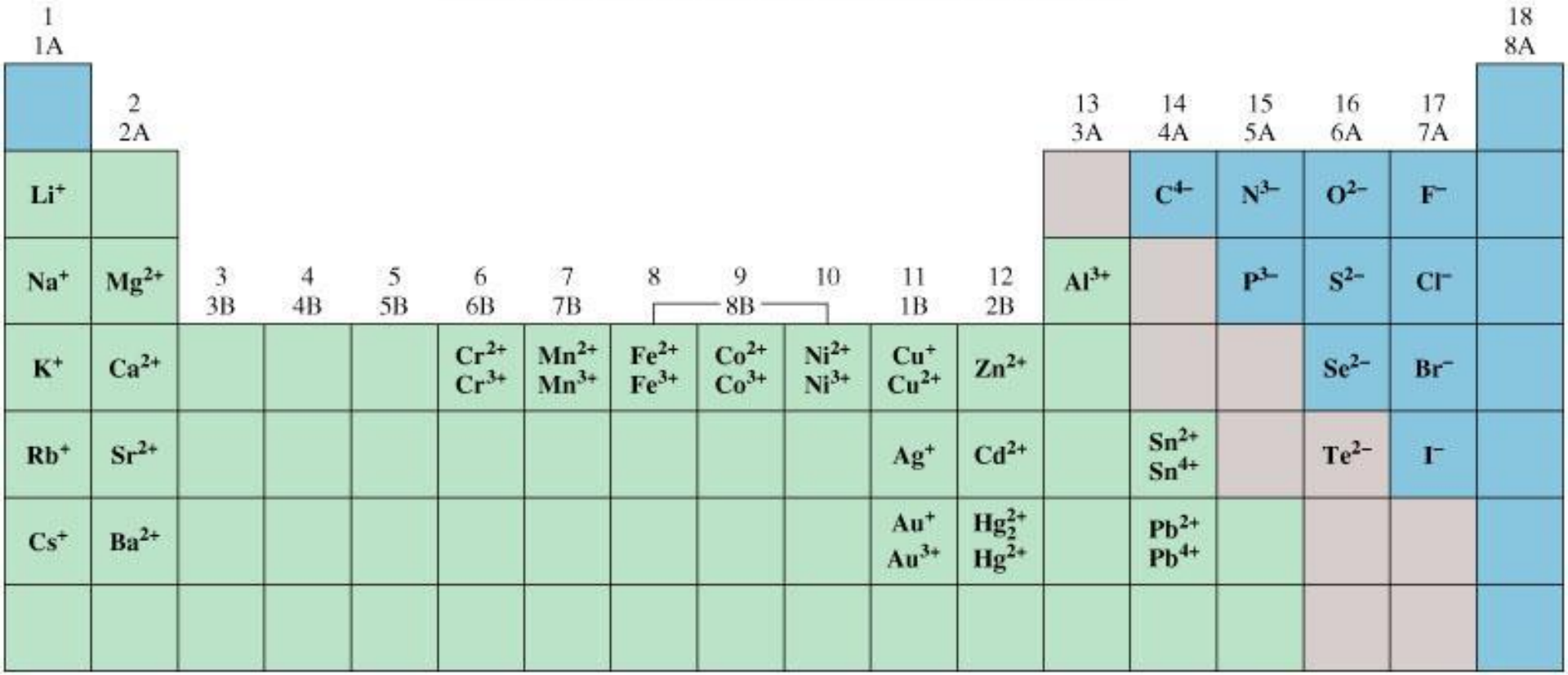
Do You Understand Ions?

How many protons and electrons are in $^{27}_{13}Al^{3+}$?

13 protons, 10 (13 – 3) electrons

How many protons and electrons are in $^{78}_{34}Se^{2-}$?

34 protons, 36 (34 + 2) electrons


1 1A
18 8A
2 2A
13 3A
14 4A
15 5A
16 6A
17 7A
3 3B
4 4B
5 5B
6 6B
7 7B
8
9
10
8B
11 1B
12 2B
Li+
Mg2+
Na+
Al3+
C4–
N3–
O2–
F–
P3–
S2–
Cl–
K+
Ca2+
Cr2+ Cr3+
Mn2+ Mn3+
Fe2+ Fe3+
Co2+ Co3+
Ni2+ Ni3+
Cu+ Cu2+
Zn2+
Se2–
Br–
Rb+
Sr2+
Ag+
Cd2+
Sn2+ Sn4+
Te2–
I–
Cs+
Ba2+
Au+ Au3+
Hg22+ Hg2+
Pb2+ Pb4+

EXAMPLE 2.5 Ions

How many protons and electrons compose the following ions? Identify each as a cation or anion.

(a) Na^{+} (b) O^{2-} (c) Cr^{3+}

EXAMPLE 2.6 Writing Isotope Symbols for Ions***

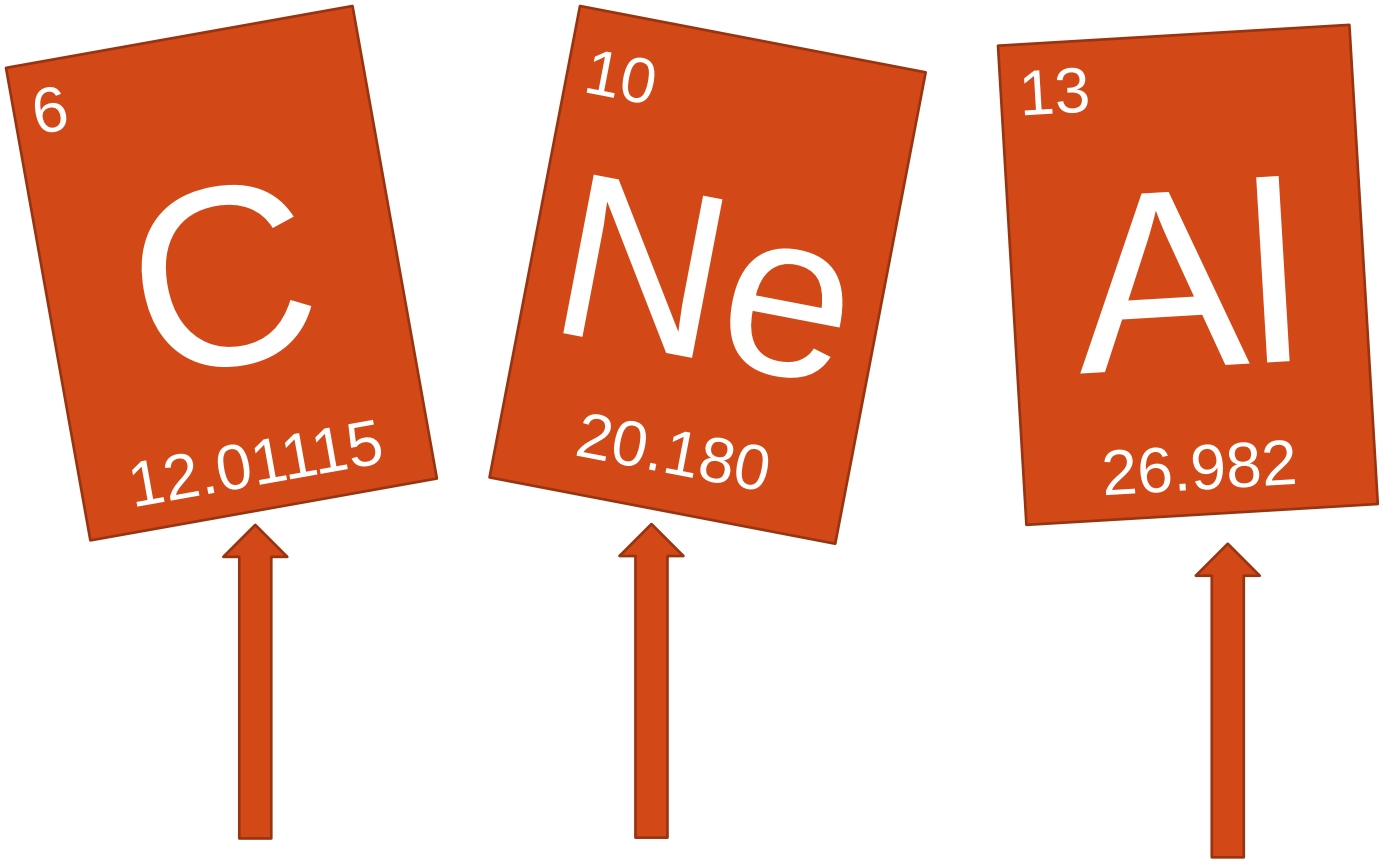
Write the isotope symbols for ions that have the following numbers of protons, neutrons, and electrons.

(a) 35 protons, 44 neutrons, and 36 electrons
(b) 13 protons, 14 neutrons, and 10 electrons
(c) 47 protons, 62 neutrons, and 46 electrons

Solution:

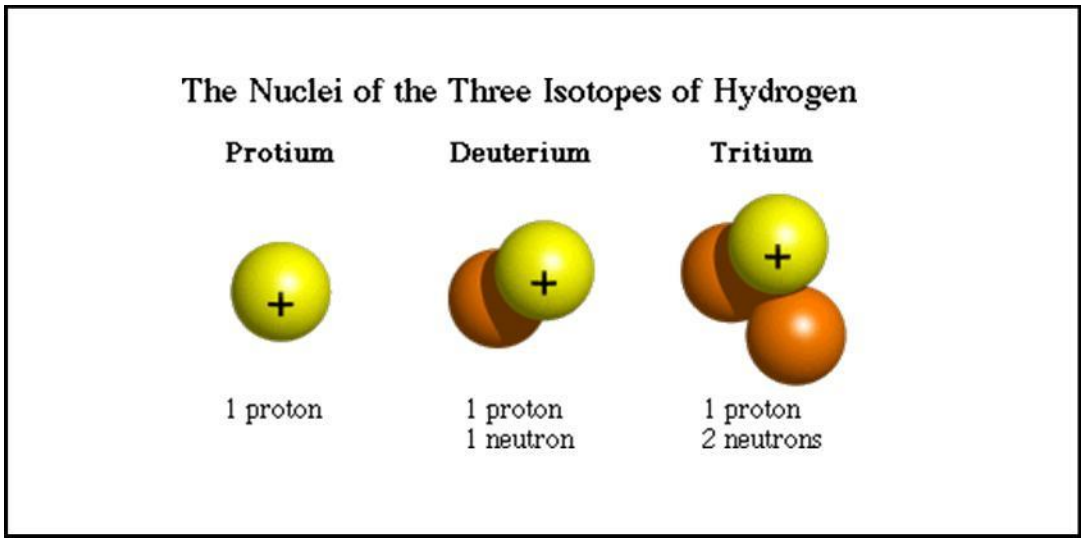
(a) The atomic number (the number of protons) is 35, indicating the element symbol is Br. The mass number is the sum of the protons and neutrons, which is 79. The charge is 1− because there is one more electron than protons. The symbol is $^{79}_{35}Br^-$.

Why does the atomic mass on the periodic table have so many decimal places?



Different concept from Mass number!!!

Atomic mass



- This atomic mass is the **one number that best represents the mass of all three versions of hydrogen**.
- No atom of hydrogen anywhere in the universe actually has this mass.
- This number is a **"weighted" average of the masses of every isotope of hydrogen**. ***(Relative atomic***

Calculating a “weighted” average

1. First, you have to know the ***mass*** of each isotope.

2. Second, you have to know the ***percent abundance**** of each isotope.

* ***Percent abundance*** is how often that particular isotope occurs in a sample of the element.

Calculating a “weighted” average

Sample of Magnesium (Mg)

A sample of magnesium collected anywhere in the universe will contain **three** isotopes of magnesium.

78.90% of this magnesium will be the isotope named “magnesium 24”
10.00% of this magnesium will be the isotope named “magnesium 25”
11.10% of this magnesium will be the isotope named “magnesium 26”

Calculating a “weighted” average

	Protons	Neutrons	Mass (amu)	% abundance
Isotope 1 (magnesium -24)	12	12	23.985045	78.90%
Isotope 2 (magnesium -25)	12	13	24.985839	10.00%
Isotope 3 (magnesium -26)	12	14	25.982595	11.10%

Calculating a “weighted” average

- Atomic mass of magnesium
  = 23.985045 x 78.90%
  + 24.985839 x 10.00%
  + 25.982595 x 11.10%
  = 24.30685245 amu

*** One atomic mass unit (1 amu) is *exactly 1/12* the mass of a carbon-12 atom.**

For your reference

How can we describe the mass of an atom of an element? Although single atoms cannot be weighed on a balance, modern techniques such as *mass spectrometry* (Figure 2.15) can be used to determine individual atomic masses accurately. For example, the mass of a single hydrogen-1 atom is 1.67380×10^{-24} g. The mass of a carbon-12 atom is 1.99272×10^{-23} g, about 12 times the mass of a hydrogen-1 atom. Numbers as small as these are difficult to remember and use. It is more convenient to think of a carbon-12 atom as being about 12 times the mass of a hydrogen-1 atom. For this reason, scientists have devised a method for expressing masses of atoms in a more convenient way. They use the atomic mass unit (amu). This mass scale uses carbon-12 (^{12}C), the most abundant isotope of carbon, as the standard to which all other atoms are compared. Carbon-12 is assigned an atomic mass of exactly 12 atomic mass units, or 12 amu. One **atomic mass unit (amu)** is equal to one-twelfth the mass of a carbon-12 atom:

$$1 \text{ amu} = \tfrac{1}{12} \times \text{mass of 1 C-12 atom} = 1.6606 \times 10^{-24} \text{ g}$$

Another example

Cl-35 is about 75.5 % and Cl-37 about 24.5% of natural chlorine.

- This atomic mass is the **one number that best represents the mass of all three versions of hydrogen**.

Exercise

Copper has two isotopes ^{63}Cu (62.9 amu) and ^{65}Cu (64.9 amu). What is the % abundance of isotope ^{63}Cu?
(Hint: Check periodic table for atomic mass)

1) 30% 2) 70% 3) 100%

Periodic Table

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Period																		
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5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.96	43 Tc [97.91]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	* 71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At [209.99]	86 Rn [222.02]
7	87 Fr [223.02]	88 Ra [226.03]	** 103 Lr [262.11]	104 Rf [265.12]	105 Db [268.13]	106 Sg [271.13]	107 Bh [270]	108 Hs [277.15]	109 Mt [276.15]	110 Ds [281.16]	111 Rg [280.16]	112 Cn [285.17]	113 Uut [284.18]	114 Fl [289.19]	115 Uup [288.19]	116 Lv [293]	117 Uus [294]	118 Uuo [294]

*Lanthanoids	*	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [144.91]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05
**Actinoids	**	89 Ac [227.03]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237.05]	94 Pu [244.06]	95 Am [243.06]	96 Cm [247.07]	97 Bk [247.07]	98 Cf [251.08]	99 Es [252.08]	100 Fm [257.10]	101 Md [258.10]	102 No [259.10]

EXAMPLE 2.7 Relative Atomic Mass

Naturally occurring chlorine consists of ^{35}Cl (34.9689 amu) and ^{37}Cl (36.9659 amu). Which isotope is most abundant?

Periodic Table

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1	1 H 1.008																	2 He 4.0026
2	3 Li 6.94	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
3	11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.085	15 P 30.974	16 S 32.06	17 Cl 35.45	18 Ar 39.948
4	19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.63	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
5	37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.96	43 Tc [97.91]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	* 71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At [209.99]	86 Rn [222.02]
7	87 Fr [223.02]	88 Ra [226.03]	** 103 Lr [262.11]	104 Rf [265.12]	105 Db [268.13]	106 Sg [271.13]	107 Bh [270]	108 Hs [277.15]	109 Mt [276.15]	110 Ds [281.16]	111 Rg [280.16]	112 Cn [285.17]	113 Uut [284.18]	114 Fl [289.19]	115 Uup [288.19]	116 Lv [293]	117 Uus [294]	118 Uuo [294]

*Lanthanoids	*	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [144.91]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05
**Actinoids	**	89 Ac [227.03]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237.05]	94 Pu [244.06]	95 Am [243.06]	96 Cm [247.07]	97 Bk [247.07]	98 Cf [251.08]	99 Es [252.08]	100 Fm [257.10]	101 Md [258.10]	102 No [259.10]

Solution:

The relative atomic mass of chlorine is 35.45 amu, as shown on the periodic table. Since the relative atomic mass is closer to the mass of ^{35}Cl (34.9689 amu) than the mass of ^{37}Cl (36.9659 amu), the ^{35}Cl isotope must be most abundant. (The actual percentages are 75.77% ^{35}Cl and 24.23% ^{37}Cl.)

Radioactive isotope

- ***Radioactive isotope***, also called ***radioisotope***, any of several species of the **same chemical element with different masses whose nuclei are unstable** and dissipate excess energy by spontaneously emitting radiation in the form of alpha, beta, and gamma rays.
- Radioactive isotopes have many useful applications. In medicine, for example, cobalt-60 is extensively employed as a radiation source to arrest the development of cancer.
- In industry, radioactive isotopes of various kinds are used for measuring the thickness of metal or plastic sheets.
- Other significant applications include the use of radioactive isotopes as compact sources of electrical power—e.g. plutonium-238 in cardiac pacemakers and spacecraft.

Radioactive isotope

- The table lists some naturally occurring radioactive isotopes.

Some significant naturally occurring radioactive isotopes	
isotope	**half-life (years, unless noted)**
^{3}H	12.32
^{14}C	$5{,}730 \times 10^{3}$
^{50}V	1.4×10^{17}
^{87}Rb	4.75×10^{10}
^{90}Sr	28.9
^{115}In	4.41×10^{14}
^{123}Te	1.3×10^{13}
^{130}Te	$>5 \times 10^{23}$
^{131}I	8.025 days

- http://www.youtube.com/watch?v=E4B94zCY4ok