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Isotopes and Calculating Mass

Isotopes

The atomic number for an element ALWAYS remains constant. So, the number of **<u>protons</u>** in an element also remains CONSTANT.

However, the number of **<u>neutrons</u>** can and often does CHANGE. Two atoms with the same atomic number but different numbers of neutrons are called **ISOTOPES** of the same element.

Application: Which of the following pairs of atoms are isotopes?

ATOM 1			ATOM 2			Are they isotopes?
p	**n**	**e**	**p**	**n**	**e**	Why?
1	0	1	1	1	1	Yes, same proton number, different neutron number
3	4	3	3	4	2	No, same proton number and neutron number (ions)
17	18	17	17	19	17	Yes, same proton number, different neutron number
8	8	8	7	8	8	No, different proton number (not same element)

Recall: to distinguish between two isotopes of the same element, use the following notation

$^{\text{mass number}}_{\text{atomic number}}$element symbol or element name – mass number

Application: Complete this table:

Name	Number of Protons	Atomic Number	Number of Neutrons	Mass Number	Symbol	Representation
protium	1	1	0	1	$^{1}_{1}H$	hydrogen-1
deuterium	1	1	1	2	$^{2}_{1}H$	hydrogen-2
tritium	1	1	2	3	$^{3}_{1}H$	Hydrogen-3

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CALCULATING AVERAGE ATOMIC MASS

Because natural isotopes exist for most elements, the masses we read from the periodic table are average masses. That's why there are often many digits after the decimal. Calculating average masses for the elements might come to you quite intuitively or you might benefit from using the following example. Either way, enjoy!

Example

Calculate the average atomic mass of silicon given the following isotopic data:

Symbol	Mass (amu)	Fractional Abundance
$^{28}_{14}Si$	27.977	92.21%
$^{29}_{14}Si$	28.976	4.70%
$^{30}_{14}Si$	29.974	3.09%

**Note: amu = atomic mass unit – 1/12 the mass of a carbon-12 atom*

1. Convert each fractional abundance from a percentage to a decimal:

$$92.21\% = 0.9221$$
$$4.70\% = 0.0470$$
$$3.09\% = 0.0309$$

2. Multiply each mass of silicon by its fractional abundance (as a decimal) and add up these values:

Average mass of silicon (in amu) = 0.9221 * 27.977 + 0.0470 * 28.976 + 0.0309 * 29.974
= 28.086 amu

Practice

Calculate the expected atomic mass for each of the following elements:

1. ^{69}Ga = 60.0%, ^{71}Ga = 40.0 %

Average mass of Ga = 60% * 69 + 40% * 71 = 69.8 amu

2. ^{64}Zn = 48.9%, ^{66}Zn = 27.8%, ^{67}Zn = 4.1%, ^{68}Zn = 18.6%, ^{70}Zn = 0.6%

Average mass of Zn = 0.489 * 64 + 0.278 * 66 + 0.041 * 67 + 0.186 * 68 + 0.006 * 70
= 65.459 amu

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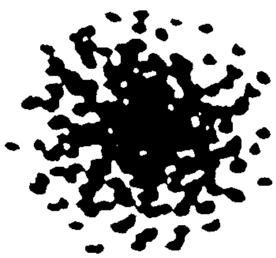
3. Cl – 35 (34.968 852 amu, 75.77%) and Cl – 37 (36.965 903 amu, 24.23%)

Average mass of Cl = 0.7577 * 34.968 852 + 0.2423 * 36.965 903 = 35.4527 amu

The Quantum Mechanical Model of the Atom

QUANTUM THEORY PROVIDES A MODERN PICTURE OF THE ATOM.

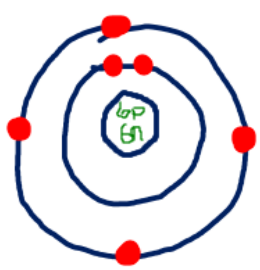
The biggest change quantum theory makes to Bohr's atom is this: electrons DO NOT have orbits, or paths, around the nucleus. Instead, they exist in **orbital**, regions of space within the atom where the **probability** of finding an electron is very high. Probability varies throughout each orbital, as in the following diagram:



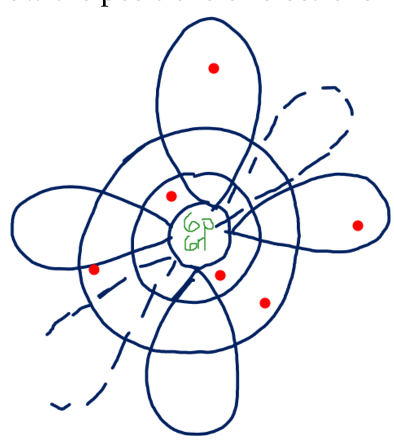
Darker = greater probability of finding an electron

Orbitals are also called **ELECTRON CLOUDS**

Translating Knowledge: Draw a diagram to show the positions of electrons in:



Bohr's Atom



The Quantum Model of the Atom

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Linking Ideas: Why is the path of an electron in Bohr's model called an orbit, but in modern theory it's called an orbital?

It is an orbit because electrons orbit (follow a path) around the nucleus.
It is an orbital because the electrons are still organized through energy levels but they are more unpredictable.

To add to the uncertainty in the quantum model, it is impossible to know precisely both where an electron is within an orbital (its **POSITION**) and how fast it's moving (its **VELOCITY**) at the same time. This is called the HEISENBERG UNCERTAINTY PRINCIPLE.