Mass Relationships of Atoms

Atomic number and mass number

Atomic number (Z) = the number of protons in the nucleus.

Mass number (A) = the sum of the number of protons + neutrons in the nucleus.

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

Symbols for a few atoms

$^{1}_{1}H$ $^{4}_{2}He$ $^{12}_{6}C$ $^{16}_{8}O$ $^{65}_{30}Zn$

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Atomic number (Z)

Element

An element is a form of matter in which all of the atoms have the same atomic number.

However, two atoms of the same element can have different mass numbers.

Isotope

Atoms that have the same atomic number but different mass numbers are called isotopes.

- **same number of protons in nucleus**
- **differ in number of neutrons**

Some isotopes

$^{1}_{1}H$	$^{12}_{6}C$	$^{16}_{8}O$	$^{235}_{92}U$
$^{2}_{1}H$	$^{13}_{6}C$	$^{17}_{8}O$	$^{238}_{92}U$
$^{3}_{1}H$	$^{14}_{6}C$	$^{18}_{8}O$	

practice problem 14

element	Atomic number	Mass number	protons	electrons	neutrons	isotope name	symbol
Neon	10	22					
Calcium	20	46					
Oxygen	8	17					
Iron	26	57					
Zinc	30	64					
Mercury	80	204					

practice problem 14

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Neon	10	22	10	10	12	Neon-22	$^{22}_{10}Ne$
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practice problem 14

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Calcium	20	46	20	20	26	Calcium-46	$^{46}_{20}Ca$
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practice problem 14

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Neon	10	22	10	10	12	Neon-22	$^{22}_{10}Ne$
Calcium	20	46	20	20	26	Calcium-46	$^{46}_{20}Ca$
Oxygen	8	17	8	8	9	Oxygen-17	$^{17}_{8}O$
Iron	26	57	26	26	31	Iron-57	$^{57}_{26}Fe$
Zinc	30	64	30	30	34	zinc-64	$^{64}_{30}Zn$
Mercury	80	204	80	80	124	mercury-204	$^{204}_{80}Hg$

Atomic masses

- **synonymous with atomic weight**
- **is a relative scale**
- **mass-12 isotope of carbon (carbon-12) is the reference atom and assigned an atomic mass of exactly 12**
- **one atomic mass unit (amu) is defined as a mass exactly equal to $^{1}/_{12th}$ the mass of one carbon-12 atom**

relative masses of carbon-12 and carbon-13 in a random sample carbon has a ratio of 1.0836129

$$\frac{{}^{13}_{6}\mathrm{C}}{{}^{12}_{6}\mathrm{C}} = 1.0836129$$

Since the atomic mass unit is defined such that the mass of ^{12}C is exactly 12 atomic mass units, then

$$\frac{{}^{13}_{6}C}{{}^{12}_{6}C} = 1.0836129$$

$$\text{Mass of } {}^{13}_{6}C = (1.0836129)(12 \text{ amu})$$

$$= 13.003355 \text{ amu}$$

Mass of an element

BUT: what does the periodic table tell us about the atomic mass of carbon?

Atomic mass is weighted average of mixture of isotopes

6
C
12.01

Atomic weight of carbon

= (atomic mass $^{12}_{6}C$) (fraction $^{12}_{6}C$)

+ (atomic mass $^{13}_{6}C$) (fraction $^{13}_{6}C$)

= (12.0000 amu)(0.9889)+(13.0035 amu)(0.0111)

= 11.8670 amu + 0.1441 amu

= 12.0111 amu

Example

Copper, a metal known since ancient times, is used in Electrical cables and pennies, among other things. The atomic masses of its two stable isotopes, $^{63}_{29}Cu$ (69.09%) and $^{65}_{29}Cu$ (30.91%), are 62.93 amu and 64.9278 amu, respectively. Calculate the average atomic mass of copper. The percentages in parentheses denote the relative abundances.

Answer

= (atomic mass $^{63}_{29}Cu$) (fraction $^{63}_{29}Cu$)

+ (atomic mass $^{65}_{29}Cu$) (fraction $^{65}_{29}Cu$)

= (62.93 amu)(0.6909)+(64.9278 amu)(0.3091)

= 43.47 amu + 20.07 amu

= 63.54 amu

practice problem 15

Boron has two naturally occurring isotopes: boron-10 (abundance = 19.8%, mass = 10.013 amu), boron-11 (abundance = 80.2%, mass = 11.009 amu). Calculate the atomic mass of boron.

10.013 amu (0.198) + 11.009 amu (0.802)

= 10.8 amu

practice problem 17

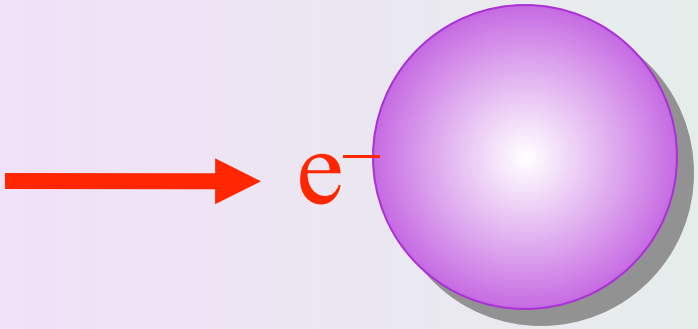
Calculate the atomic mass of magnesium. The three magnesium isotopes have atomic masses and relative abundances of 23.985 amu (78.99%), 24.986 amu (10.00%), and 25.982 amu (11.01%)

23.985 amu (0.7899) + 24.986 amu (0.1000) + 25.982 amu (0.1101)

= 24.30 amu

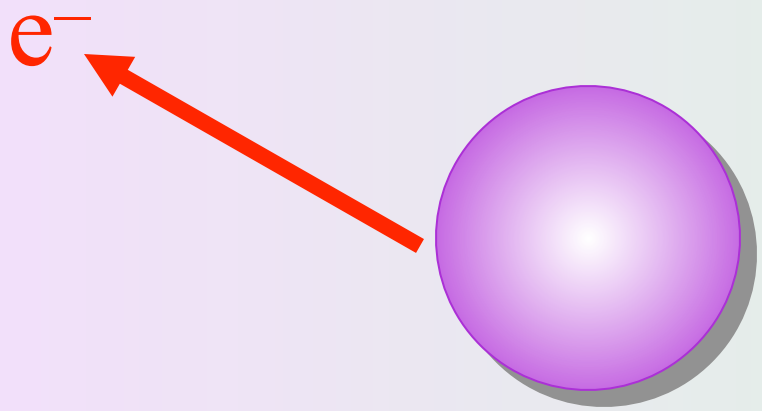
Experimental Determination Of Atomic & Molecular Masses

Atomic mass is measured by mass spectrometry



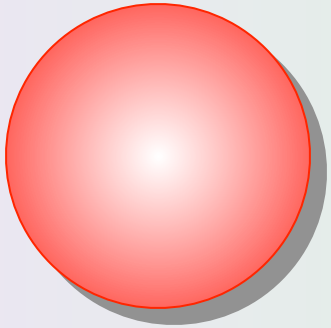
Atom is bombarded by stream of high Energy electrons.

Atomic mass is measured by mass spectrometry



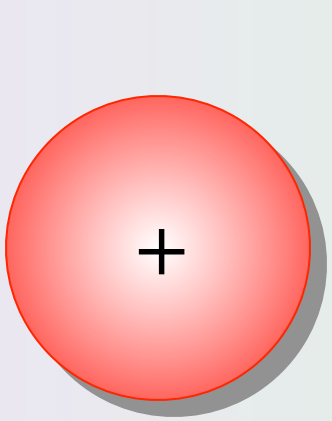
Electron collides with atom, “bounces” off

Atomic mass is measured by mass spectrometry



and transfers some of its energy to it.

Atomic mass is measured by mass spectrometry



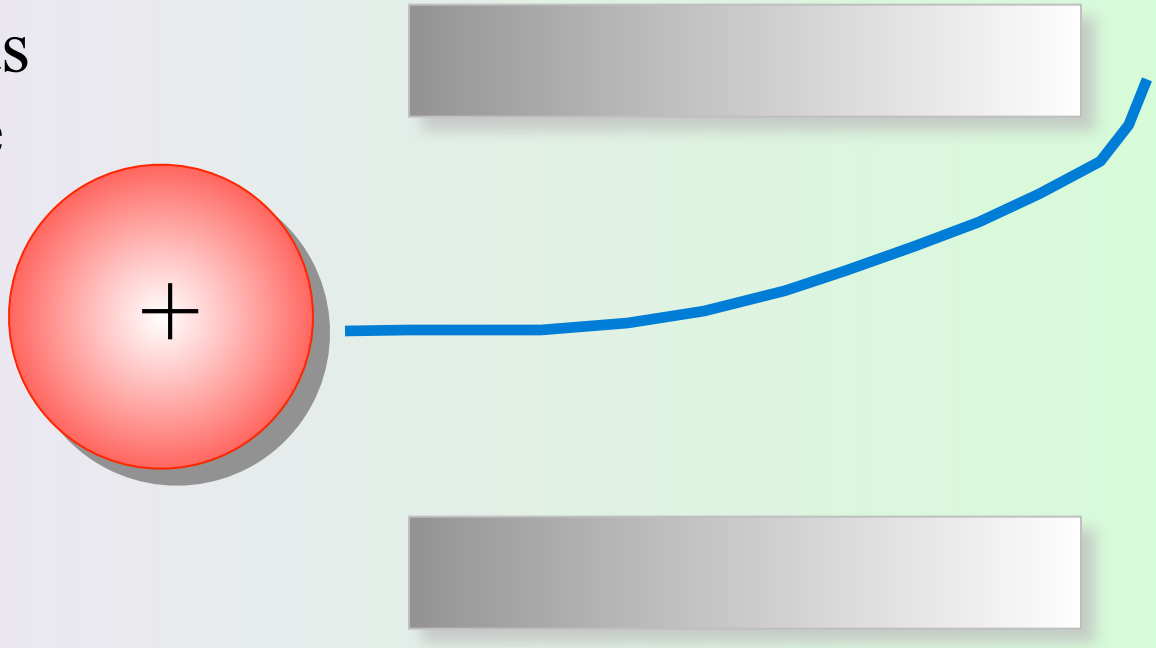
Atom dissipates its excess energy by expelling one of its electrons.

Ion is deflected by magnetic field

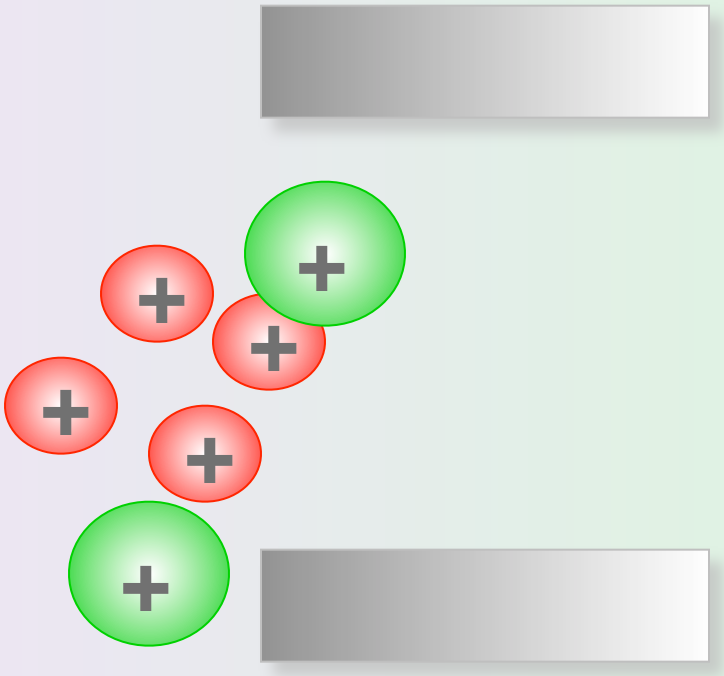
amount of deflection depends on mass to charge ratio

highest m/z
deflected least

lowest m/z
deflected most

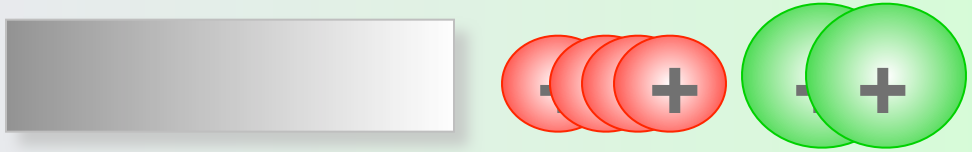


Ions are detected after passage through magnetic field



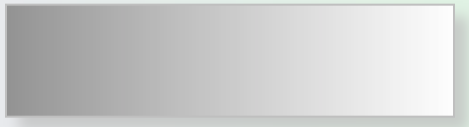
Ions are detected after passage through magnetic field

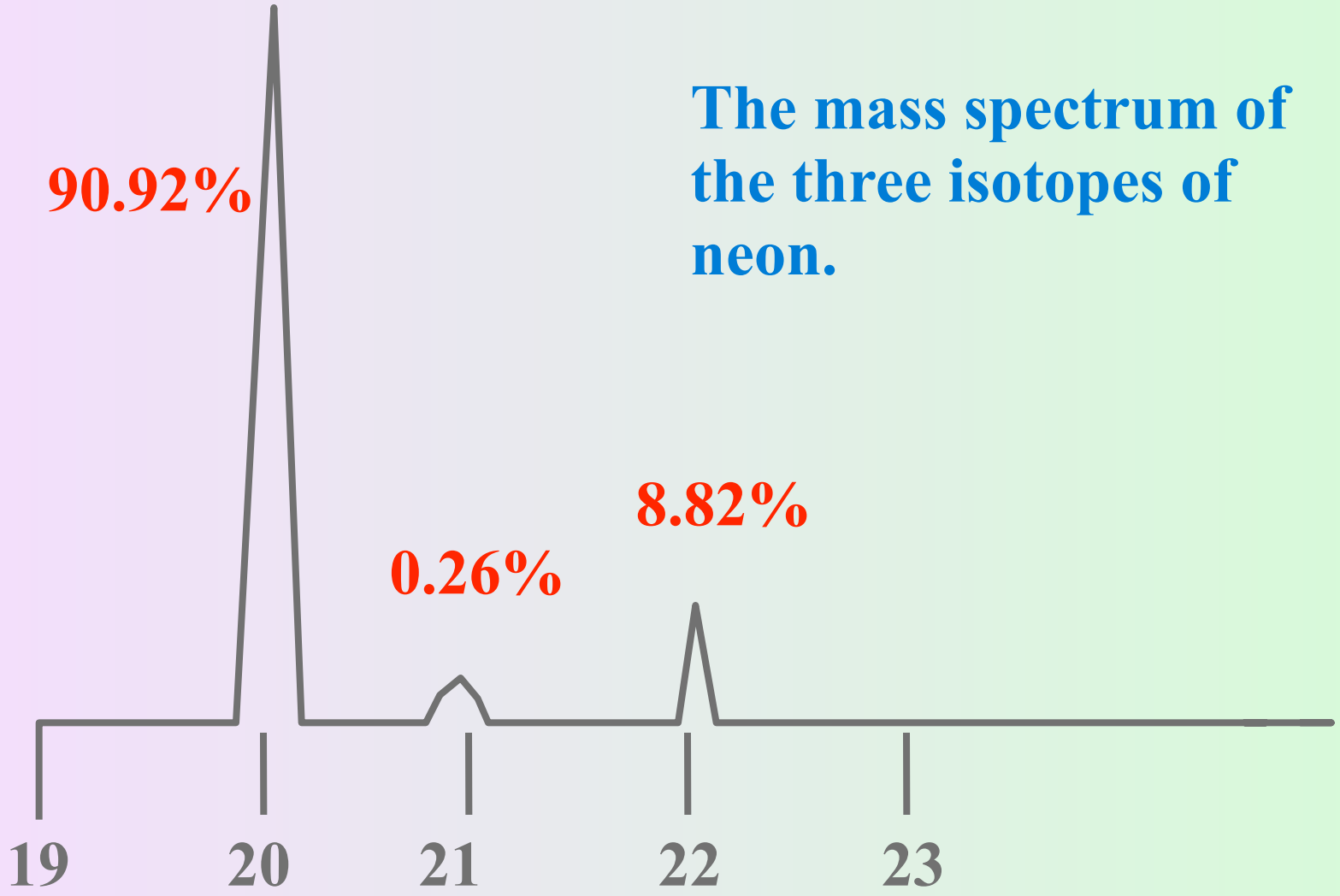
mixture of ions of different mass gives separate peak for each m/z



intensity of peak proportional to percentage of each atom of different mass in mixture

separation of peaks depends on relative mass





The mass spectrum of the three isotopes of neon.