

[TP] Which of the following contains the smallest number of atoms?

40% 1. 187 g of liquid mercury, Hg
7% 2. 1400 u of uranium, U
20% 3. 6×10^{24} atoms of sodium, Na
33% 4. 2 mol of hydrogen gas, H_2

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Lecture 1 CH131 Summer 1

Wednesday, May 20, 2020

Begin Ch1: The atom in modern chemistry

- Periodic table: Master key to chemistry
- Isotopes → atomic weight
- Chemist's dozen: The mole

Next: Example problems; Ch 2: Chemical formulas, equations, and reaction yields

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Periodic table: The master key to chemistry

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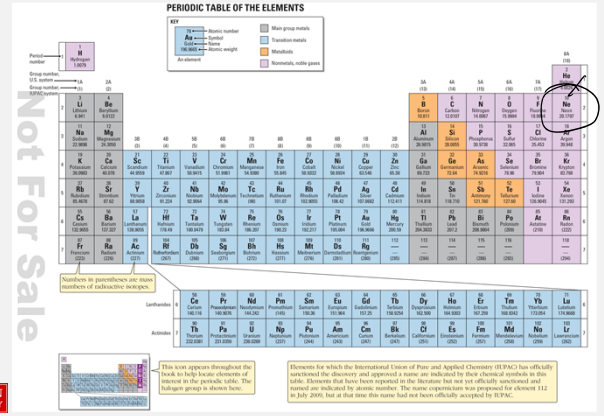

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Periodic table: The master key to chemistry

$^{A}_{Z}X$ ← chemical symbol; A ← mass number; Z ← atomic number

Z = # of protons = # of electrons

A = # neutrons + # of protons

$= N + Z$

$N = A - Z$

	17	
r	Cl	Ar
5	Chlorine	39
	35.453	

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Isotopes → atomic weight

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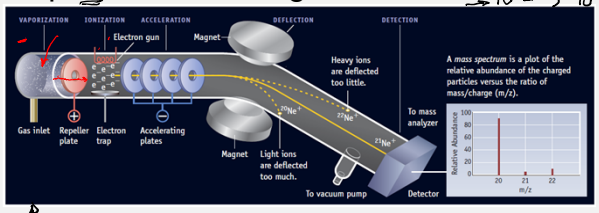
Mass spectrometer "weighs" atoms

$^{20}_{10}Ne$ $^{21}_{10}Ne$ $^{22}_{10}Ne$



Strip away an electron, accelerate positive ions, and then deflect them in a magnetic field.

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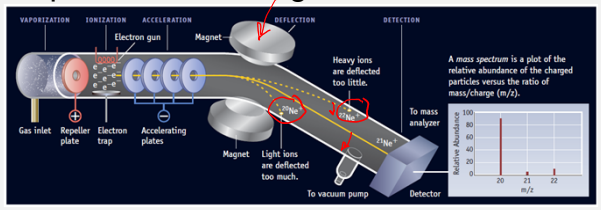
Mass spectrometer "weighs" atoms



Strip away an electron, accelerate positive ions, and then deflect them in a magnetic field.

Less deflection, heavier mass

$^{20}_{10}Ne^{+}$ 10N + 10P

$^{21}_{10}Ne^{+}$ 11N + 10P

$^{22}_{10}Ne^{+}$ 12N + 10P

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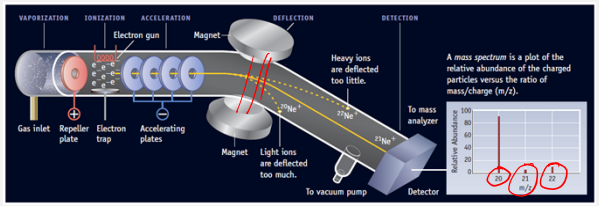
Mass spectrometer "weighs" atoms



Strip away an electron, accelerate positive ions, and then deflect them in a magnetic field.

Less deflection, heavier mass

Neon has three "isotopes": ^{20}Ne, ^{21}Ne, and ^{22}Ne

Relative peak heights → isotopic abundance

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Average mass of CH131 students?

75 students weigh 100 lbs

100 students weigh 150 lbs

50 students weigh 200 lbs

Sketch the "mass spectrum" of the class, using just "counts" for the vertical axis

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Average mass of CH131 students?

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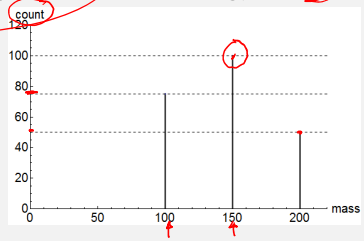
Sketch the "mass spectrum" of the class, using just "counts" for the vertical axis



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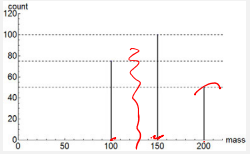
[TP] For our hypothetical class,
75 students weigh 100 lbs,
100 students weigh 150 lbs, and
50 students weigh 200 lbs.

Based on your "mass spectrum" sketch, roughly (guesstimate), what will the average be?

6% 1. Less than 100
89% 2. Between 100 and 150
6% 3. Between 150 and 200
0% 4. Greater than 200



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Average mass of CH131 students?

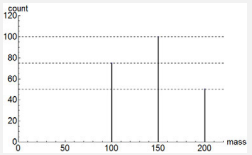
75 students weigh 100 lbs

100 students weigh 150 lbs

50 students weigh 200 lbs

What is the expression for the fraction of students with mass 150 lbs, f_{150}?

$f_{150} = \frac{\#\text{ of mass } 150}{\text{total}} = \frac{100}{225}$



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Average mass of CH131 students?

75 students weigh 100 lbs

100 students weigh 150 lbs

50 students weigh 200 lbs

In terms of f_{100}, f_{150}, and f_{200}, write the expression that evaluates to the exact average.

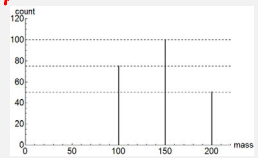
A $(f_{100} + f_{150} + f_{200})/3$

B $f_{100} * 100 + f_{150} * 150 + f_{200} * 200$

$\frac{75}{225} * 100 + \frac{100}{225} * 150 + \frac{50}{225} * 200$

$\frac{75*100 + 100*150 + 50*200}{225}$

$\frac{\text{total mass}}{\#\text{Student}} = \text{average mass}$



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Average mass of CH131 students?

75 students weigh 100 lbs

100 students weigh 150 lbs

50 students weigh 200 lbs

total mass = 75 × 100 lbs + 100 × 150 lbs + 50 × 200 lbs

average mass = total mass / (75 + 100 + 50)

= total mass / 225

= (75/225) × 100 lbs + (100/225) × 150 lbs + (50/225) × 200 lbs

= f_{100} × 100 lbs + f_{150} × 150 lbs + f_{200} × 200 lbs

225

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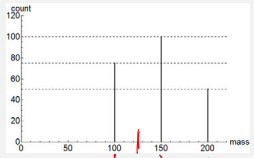
[TP] For our hypothetical class, average weight of a CH131 student is 144 lbs. Which of the following statements is true for this class?

0% 1. The weight of each student is 144 lbs

61% 2. No student weighs 144 lbs

39% 3. Neither of the statements is true.



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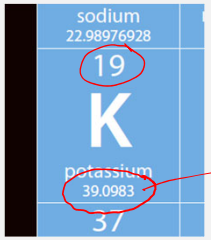
Element identity and atomic number Z



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analogous to 1+4 oxygen structural mass

Number of protons = atomic number $Z = 19$

Relative atomic weight = 39.0983

Where does the number 39.0983 come from?

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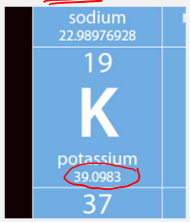
Atoms of an element come in different "flavors"

Atoms with the same number of protons ...
but with different numbers of neutrons ...
are chemically the same ...
but have different masses

We call such different flavors of atoms of an element isotopes

39.0983 u is the average mass of the different kinds of atoms (isotopes) of K that are in a sample of K.

atomic mass unit.



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Atomic mass unit u

① 1 u is exactly $\frac{1}{12}$ of the mass of just one atom of ^{12}C, ^{13}C, ^{14}C
6, 6, 6

② Exactly 12 g of ^{12}C atoms contains Avogadro's number, N_A, of atoms

$N_A = 6.02214 \times 10^{23}$ atoms =

one atom ^{12}C = $\frac{12\ g}{N_A} = 1.99265 \times 10^{-23}$ g

$1\ u = \frac{1}{12} * 12\ g/N_A = \frac{g}{N_A} = 1.66054 \times 10^{-24}$ g

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Atomic mass unit u

^{16}O

1 u defined to be exactly (1/12) mass of 1 atom of ^{12}C

Exactly 12 g of ^{12}C contains $N_A = 6.02214 \times 10^{23}$ atoms

Therefore, the mass of one ^{12}C atom is ...

$12\ g/N_A = 1.99265 \times 10^{-23}$ g

And so, 1 u = ...

$(1/12) \times 1.99265 \times 10^{-23}\ g = 1.66054 \times 10^{-24}$ g

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Average mass of an atom of K

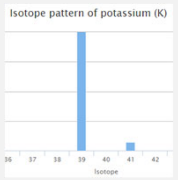
Two isotopes: K-39 and K-41

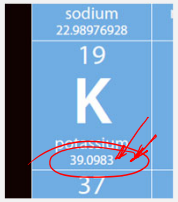
K-39 peak at 38.9637 u, height 933

K-41 peak at 40.9618 u, height 67

Write and then evaluate the expression whose value is the average mass in u of an atom of K.

f_{39} 38.9637 u + f_{41}40.9618 u = 39.098 u





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Average mass of an atom of K

Two isotopes: K-39 and K-41

K-39 peak at 38.9637 u, height 933

K-41 peak at 40.9618 u, height 67

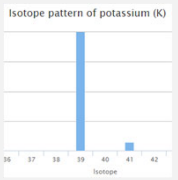
The average mass in g of an atom of K is

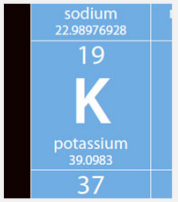
$= 39.098$ u

$= 39.098 \times (1/12) \times 12\ \text{g} \times (1/N_\text{A})$

$= 39.098\ \text{g} / N_\text{A}$

$= 6.4923 \times 10^{-23}$ g





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Average mass of any atom

The average mass of an atom of K is 39.098 g/N_A

The average mass of an atom of Br is 79.904 g/N_A

The average mass of an atom of H is 1.008 g/N_A

The average mass of any atom in g/N_A is the number given on the periodic table.

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Molar mass of any element

Molar mass is the mass of N_A "average" atoms of an element.

The average mass of an atom of K is 39.098 g/N_A

The molar mass of K is $N_\text{A} \times (39.098\ \text{g}/N_\text{A}) = 39.098$ g

The molar mass of Br is 79.904 g

The molar mass of H is 1.008 g

The molar mass of any element in g is the number given on the periodic table.

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Atomic weight = magnitude of average mass

The atomic weight of K is 39.098 (no units!)

The atomic weight of Br is 79.904

The atomic weight of H is 1.008

The atomic weight of an element is the number given on the periodic table.

[TP] The molar mass of Cl is 35.453 g. ^{37}Cl has a natural abundance of 24.24%. Which of the following statements is true?

5% 1. The mass of one atom of naturally occurring Cl is 35.453 g divided by Avogadro's number

95% 2. The mass of one atom of naturally occurring Cl cannot be 35.453 g divided by Avogadro's number.

0% 3. Neither of the statements is true.

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Terms to distinguish

Relative atomic mass, A_r: ratio of mass of an isotope relative to mass of 1/12 of one ^{12}C atom

A_r of ^{13}C is 13.00335 (unitless)

Atomic mass unit, u: 1/12 mass of one ^{12}C atom

$1\ u = (1/12) \times (12\ g) / N_A = g / N_A = 1.66054 \times 10^{-24}\ g$

Atomic weight: average of relative atomic masses of an element

Atomic weight of C is 12.01 (unitless)

Molar mass, M: Mass in grams numerically equal to atomic weight; that is, the mass in grams of N_A "average atoms" of an element

Molar mass of C is 12.01 g

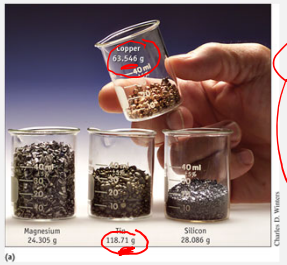
Chemist's dozen: mole → counting by weighing

Mole: Count by weighing

The mass in g of 1 mol of any element is called its molar mass

Number of particles in 1 mol is $N_A = 6.022140857 \times 10^{23}$

Each of these amounts contains the same number of atoms



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[TP] Which of the following contains the smallest number of atoms?

33%	1.	187 g of liquid mercury, Hg
67%	2.	1400 u of uranium, U
0%	3.	6×10^{24} atoms of sodium, Na
0%	4.	2 mol of hydrogen gas, H_2

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