 Copyright © 2020 Dan Dill dan@bu.edu

[TP] What is the value of $\frac{877.15 \times 1067.4}{2371} - 392$ to the correct number of significant figures?

17% 1. 2.88398
17% 2. 2.8840
17% 3. 2.884
17% 4. 2.9
17% 5. 3
17% 6. 2

BOSTON UNIVERSITY

0 1 9

1

Lecture 2 CH131 Fall 2020

Tuesday, September 8, 2020

- Review: Significant figures
- Mass of atoms
- Isotopes and average atomic mass
- Atomic mass unit and Avogadro's number
- Atomic weight

Next: Chemist's dozen: The mole; Ch 2: Chemical formulas, equations, and reaction yields

BOSTON UNIVERSITY

2

 Copyright © 2020 Dan Dill dan@bu.edu

[TP] What is the value of $\frac{877.15 \times 1067.4}{2371} - 392$ to the correct number of significant figures?

1% 1. 2.88398
10% 2. 2.8840
43% 3. 2.884
6% 4. 2.9
5% 5. 2
36% 6. 3

392.000

114354

BOSTON UNIVERSITY

152 of 192 3 0

3

 Copyright © 2020 Dan Dill dan@bu.edu

Review: Significant figures

$\frac{877.15 \times 1067.4}{2371} - 392 = 394.9 - 392$

$394.9 - 392 = 395 - 392 = 3$

394.9 → 395
392.?
395 − 392 = 3

394.9, 8, 7, 6, 5 → 395
394.4, 3, 2, 1, 0 → 394

BOSTON UNIVERSITY

4

4

Copyright © 2020 Dan Dill dan@bu.edu

 Copyright © 2020 Dan Dill dan@bu.edu

Atomic mass and molecular mass

Atomic mass is the (dimensionless) ratio of the mass of a particular atom to the mass of a reference atom.

The reference atom is the most abundant isotope (we will discuss isotopes shortly) of carbon that is assigned the atomic mass 12.

This means the mass of an S atom is $\frac{32.065}{12}$ = 2.6721 times as heavy as the reference carbon atom.

5 B Boron 10.81	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984
13 Al Aluminum 26.98	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.45
31 Ga	32 Ge	33 As	34 Se	35 Br

BOSTON UNIVERSITY

5

 Copyright © 2020 Dan Dill dan@bu.edu

[TP] What is the molecular mass of CS_2?

0% 1. 32.065

2% 2. 44.076

72% 3. 76.140 ✓ 76.141

26% 4. Something else

5 B Boron 10.81	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984
13 Al Aluminum 26.98	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.45
31 Ga	32 Ge	33 As	34 Se	35 Br

76.140
76.141

12.011
32.065
32.065
76.141

12.0107
32.065
32.065

114354

BOSTON UNIVERSITY

170 of 192

6

0

6

 Copyright © 2020 Dan Dill dan@bu.edu

[TP] What is the mass percent of oxygen in NO_2?

0% 1. 46.7%

2% 2. 53.3%

83% 3. 69.6% ✓

2% 4. 30.4%

13% 5. Something else

5 B Boron 10.81	6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984
13 Al Aluminum 26.98	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.45
31 Ga	32 Ge	33 As	34 Se	35 Br

$$\frac{\text{mass of O in } NO_2}{\text{mass of } NO_2} * 100\% = \frac{2 \times 15.9994}{2 * 15.9994 + 14.0067} * 100\%$$

114354

BOSTON UNIVERSITY

173 of 192

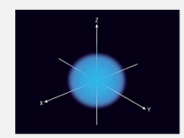
8

0

8

 Copyright © 2020 Dan Dill dan@bu.edu

Atom composition



Atoms consist of positively charged protons, negatively charged electrons, and neutral neutrons.

The volume of the atom is due to its electron cloud.

The mass of the atom is due to the protons and neutrons packed into a much smaller nucleus.

The radius of the electron cloud 10^5 larger than that of the nucleus.

The mass of the proton and neutron are about the same, but each nearly 2000 times as larger than that of the electron.

BOSTON UNIVERSITY

13

13

Copyright © 2020 Dan Dill dan@bu.edu

 Copyright © 2020 Dan Dill dan@bu.edu

Atom composition

Because atoms are electrically neutral, atoms contain equal numbers of electrons and protons.

All atoms of the same element have the same number of protons (and electrons).

Different elements have different numbers of protons (and electrons).

Atoms of an element can have different numbers of neutrons, and such atoms are called isotopes of the element.

Because the electron cloud is the same for every isotope of an element, each isotope has the same chemical properties.

BOSTON UNIVERSITY 14

14

 Copyright © 2020 Dan Dill dan@bu.edu

Isotopes and average atomic mass

The composition of an atom is indicated as $^{A}_{Z}X$, where X is the element symbol, atomic number Z is the number of protons, and the mass number A is the number of protons plus the number of neutrons.

As example, the isotopes of carbon are $^{20}_{10}$Ne, $^{21}_{10}$Ne, and $^{22}_{10}$Ne, with 10, 11, and 12 neutrons, respectively.

#p + #n

Z → #p = #e

BOSTON UNIVERSITY 15

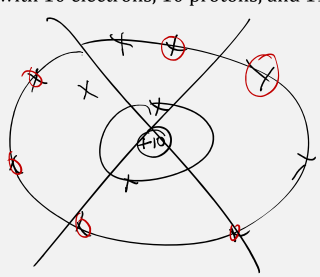
15

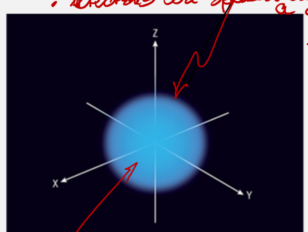
 Copyright © 2020 Dan Dill dan@bu.edu

Isotopes and average atomic mass

Sketch an atom of $^{21}_{10}$Ne, with 10 electrons, 10 protons, and 11 neutrons.

cloud of delocalized charge
• electrons are not moving
• electrons are spread out in a cloud of charge





total charge of cloud is −10e

BOSTON UNIVERSITY 16

16

 Copyright © 2020 Dan Dill dan@bu.edu

[TP] Chlorine has two isotopes, $^{35}_{17}$Cl and $^{37}_{17}$Cl, with atomic mass 34.969 and 36.966, respectively. The natural abundance of $^{35}_{17}$Cl is 75.78%. The average atomic mass of chlorine is ...

0%	1.	34.969
5%	2.	(34.969 + 36.966)/2
87%	3.	0.7578×34.969 + (1 − 0.7578)×36.966 = 35.45
1%	4.	36.966
6%	5.	Something else

114354

175 of 192 0

BOSTON UNIVERSITY 18

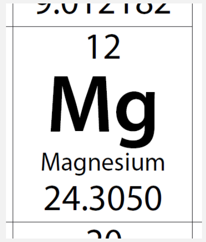
18

Copyright © 2020 Dan Dill dan@bu.edu

 Copyright © 2020 Dan Dill dan@bu.edu

[TP] What is the least abundant isotope of magnesium?

7% 1. $^{24}_{12}$Mg
34% 2. $^{26}_{12}$Mg
59% 3. More information needed



114354

176 of 192

0

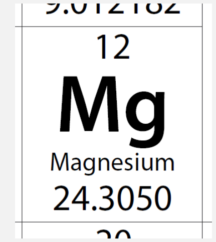
BOSTON UNIVERSITY

19

 Copyright © 2020 Dan Dill dan@bu.edu

Isotopes and average atomic mass

To calculate abundances from the average atomic mass of an element, we must know its naturally occurring isotopes.



For magnesium, there are three.

$^{24}_{12}$Mg	23.985 041 90	78.99
$^{25}_{12}$Mg	24.985 837 02	10.00
$^{26}_{12}$Mg	25.982 593 04	11.01

$$24.3050 = f_{24} \times {}^{24}_{12}\text{Mg} + f_{25} \times {}^{25}_{12}\text{Mg} + f_{26} \times {}^{26}_{12}\text{Mg}$$

$$f_{24} = 0.7899, \text{ etc.}$$

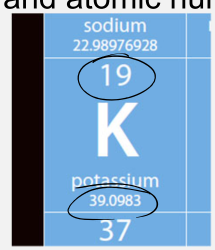
BOSTON UNIVERSITY

20

20

 Copyright © 2020 Dan Dill dan@bu.edu

Element identity and atomic number Z



$_{19}$K

Number of protons = atomic number $Z = 19$
Relative atomic weight = 39.0983
Where does the number 39.0983 come from?

BOSTON UNIVERSITY

22

22

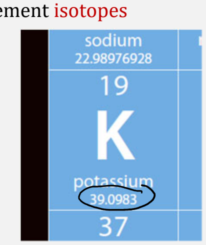
 Copyright © 2020 Dan Dill dan@bu.edu

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.



BOSTON UNIVERSITY

23

23

Copyright © 2020 Dan Dill dan@bu.edu

Atomic mass unit u

BOSTON UNIVERSITY 24

24

Atomic mass unit u

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

Exactly 12 g of ^{12}C contains N_A = 6.02214076 × 10^{23} atoms (Avogadro's number)

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

BOSTON UNIVERSITY 25

25

Average mass of an atom of K

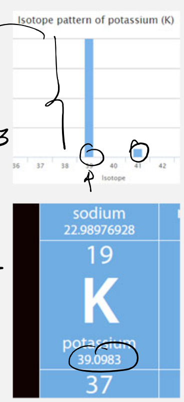
Two isotopes: K-39 and K-41

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



BOSTON UNIVERSITY 26

26

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

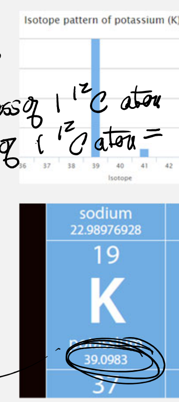
The average mass in g of an atom of K is

= 39.098 u

= 39.098 × (1/12) × 12 g × (1/N_A)

= 39.098 g / N_A

= 6.4923×10^{-23} g



BOSTON UNIVERSITY 27

27

 Copyright © 2020 Dan Dill dan@bu.edu

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.

BOSTON UNIVERSITY 28

28

Lecture 2 CH131 Fall 2020 Copyright © 2020 Dan Dill dan@bu.edu

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_A × (39.098 g/N_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.

BOSTON UNIVERSITY 29

29

Lecture 2 CH131 Fall 2020 Copyright © 2020 Dan Dill dan@bu.edu

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.

BOSTON UNIVERSITY 30

30

Copyright © 2020 Dan Dill dan@bu.edu