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

27% 1. 2.88398
0% 2. 2.8840
36% 3. 2.884
9% 4. 2.9
18% 5. 3
9% 6. 2

930 185

11 of 15

1

0

BOSTON UNIVERSITY

1

Lecture 1 CH131 Summer 1 2021

Monday, May 24, 2021

- Course overview
- What we will cover and how to master it
- Dimensional analysis & significant figures

Begin Ch1: The atom in modern chemistry

- Mass of atoms
- Isotopes and average atomic mass
- Atomic mass unit and Avogadro's number

Next: Atomic weight; Chemist’s dozen: The mole; Example problems; Ch 2: Chemical formulas, equations, and reaction yields

BOSTON UNIVERSITY

2

Course overview

The course is given by

Lecture: Dan Dill (dan@bu.edu)
Discussion: Matt Rotondaro (mattroto@bu.edu)
Lab: Jose Luis Medrano Jr (medrano@bu.edu)

BOSTON UNIVERSITY

6

6

Website and Blackboard

The course syllabus website is

http://genchem.bu.edu/ch131-summer-1-2021/

The course Blackboard at https://learn.bu.edu is “CH131 Summer 1 2021”

This course is given entirely online, using Zoom and links to all Zoom meetings are at the “Zoom meetings links” tab on Blackboard.

Well see how in a moment.

BOSTON UNIVERSITY

7

7

Lectures

Lectures are Monday—Thursday 10 am—noon GMT-4

- There is no lecture Monday, May 31 (a holiday)
- There is lecture Friday, June 4 (holiday makeup)

BOSTON UNIVERSITY 8

8

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

Discussions

Discussions are Tuesday—Thursday 9—9:50 AM GMT-4

- The first discussion is tomorrow, Tuesday, May 25.

BOSTON UNIVERSITY 9

9

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

Labs

Labs are Monday and Wednesday, 9 AM—noon GMT-4

- The first lab is Wednesday, May 25.
- Note that there is a lab Friday, June 4, on account of the May 31 holiday

BOSTON UNIVERSITY 10

10

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

Online meeting Zoom links

How to access the online meetings for lecture, lab, discussion, and office hours are detail at

- http://genchem.bu.edu/ch131-summer-1-2021/syllabus.html#times
- http://genchem.bu.edu/ch131-summer-1-2021/syllabus.html#officeHours

Access Zoom at https://bostonu.zoom.us

- BU Username, be sure to omit “@bu.edu”
- BU password

BOSTON UNIVERSITY 11

11

Quizzes and the final exam

There will be five lecture quizzes, the first class day of each week:

Tuesday, June 1, at 2—4 PM GMT-4

Mondays, June 7, 14, 21, and 28, at 2—4 PM GMT-4

The final exam is Thursday, July 1, 1—4 PM GMT-4, in place of both discussion and lecture that day.

BOSTON UNIVERSITY 12

12

Course grade

Course grade is based on your overall course score

http://genchem.bu.edu/ch131-summer-1-2021/syllabus.html#grading

Contribution to overall course score	
Quizzes (lowest score dropped)	50%
Final exam	20%
Lab	15%
Lecture participation	10%
Discussion participation	5%

Your scores for each part of the course will always be available to you on Blackboard, at https://learn.bu.edu

BOSTON UNIVERSITY 13

13

Lecture participation

Questions asked during each lecture are answered using the

TurningPoint mobile app

To receive credit, you must have an account using your bu.edu email address and have purchased a subscription,

http://genchem.bu.edu/ch131-summer-1-2021/syllabus.html#materials

BOSTON UNIVERSITY 14

14

Other questions?

Please refer to the course website

http://genchem.bu.edu/ch131-summer-1-2021/

and the Piazza discussion forum

https://piazza.com/bu/summer2021/ch131summer12021/

Questions of a personal nature to dan@bu.edu.

BOSTON UNIVERSITY 15

15

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

What we will learn

We will cover portions of the chapters 1—3 and 9—17 and related problems of Oxtoby et al., 8e

The required assigned problems are at

http://genchem.bu.edu/ch131-summer-1-2021/syllabus.html#lecture

BOSTON UNIVERSITY 19

19

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

What we will learn

We will cover portions of the following chapters and related problems of Oxtoby et al. The **detailed schedule** is here and the **calendar of lectures and disussions** is here.

Chapter and required problems	Lectures	Discussions
Chapter 1. The atom and modern chemistry Chapter 1 problems: 5, 7, 11, 13, 17, 19, 21, 23, 25, 27, 31, 33, 35 Appendix A problems: 1, 7, 11, 13, 17, 19 Appendix B.1 problems: 1, 7, 9 Appendix C.3 problems: 13, 17, 19	May 24	May 25
Chapter 2.1--2.6. Chemical formulas, equations, and reaction yields: Chapter 2 problems: 1, 5, 7, 11, 13, 19, 21, 23, 25, 27, 29, 31, 35, 37, 49	May 25–26	May 26
Chapter 3.1--3.11. Chemical bonding: The classical description: Chapter 3 problems: 9, 15, 21, 23, 33, 39, 41, 43, 45, 47, 51, 53, 55, 57, 59, 61, 65, 69	May 26–27	May 27
Chapter 9.1--9.6. The gaseous state: Chapter 9 problems: 5, 9, 11, 19, 21, 25, 27, 31, 33, 35, 37, 41, 43, 47	May 27–June 4	June 1–3

BOSTON UNIVERSITY 20

20

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

What we will learn

Your singular focus should be to master them.

The better you do so, the better you will do in this course.

BOSTON UNIVERSITY 22

22

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

Let's begin

Essential in solving problems in this course is dimensional analysis and proper accounting for significant figures.

Let's illustrate these with the following problem.

BOSTON UNIVERSITY 23

23

Time, distance, and speed

Google says the speed of light (in a vacuum) is 299 792 458 m/s.

Google says the star Betelgeuse is 700 ly (light years) from Earth.

How far away is Betelgeuse, in km (kilometers)?

1 ly = 299792458 m/s * 3600 s/hr * 24 hr/day * 365.25 day/yr yr

BOSTON UNIVERSITY 24

24

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

Time, distance, and speed

Google says the speed of light (in a vacuum) is 299 792 458 m/s.

Google says the star Betelgeuse is 700 ly (light years) from Earth.

How far away is Betelgeuse, in km (kilometers)?

$$1\ \text{ly} = \frac{299792458\ \text{m}}{\text{s}} \times \frac{3600\ \text{s}}{\text{hr}} \times \frac{24\ \text{hr}}{\text{day}} \times \frac{365.25\ \text{day}}{\text{yr}}\,\text{yr}$$

BOSTON UNIVERSITY 25

25

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

Time, distance, and speed

Google says the speed of light (in a vacuum) is 299 792 458 m/s.

Google says the star Betelgeuse is 700 ly (light years) from Earth.

How far away is Betelgeuse, in km (kilometers)?

$$1\ \text{ly} = \frac{299792458\ \text{m}}{\text{s}} \times \frac{3600\ \text{s}}{\text{hr}} \times \frac{24\ \text{hr}}{\text{day}} \times \frac{365.25\ \text{day}}{\text{yr}}\,\text{yr} = 9.4607 \times 10^{15}\ \text{m}$$

BOSTON UNIVERSITY 26

26

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 Dan Dill dan@bu.edu

Time, distance, and speed

Google says the speed of light (in a vacuum) is 299 792 458 m/s.

Google says the star Betelgeuse is 700 ly (light years) from Earth.

How far away is Betelgeuse, in km (kilometers)?

$$1\ \text{ly} = \frac{299792458\ \text{m}}{\text{s}} \times \frac{3600\ \text{s}}{\text{hr}} \times \frac{24\ \text{hr}}{\text{day}} \times \frac{365.25\ \text{day}}{\text{yr}}\,\text{yr} = 9.4607 \times 10^{15}\ \text{m}$$

See https://en.wikipedia.org/wiki/Light-year as a check.

BOSTON UNIVERSITY 27

27

Time, distance, and speed

Google says the speed of light (in a vacuum) is 299 792 458 m/s.

Google says the star Betelgeuse is 700 ly (light years) from Earth.

How far away is Betelgeuse, in km (kilometers)?

$$1\ \text{ly} = \frac{299792458\ \text{m}}{\text{s}} \times \frac{3600\ \text{s}}{\text{hr}} \times \frac{24\ \text{hr}}{\text{day}} \times \frac{365.25\ \text{day}}{\text{yr}}\ \text{yr} = 9.4607 \times 10^{15}\ \text{m}$$

$$\text{distance} = 700\ \text{ly} \times \frac{9.4607 \times 10^{15}\ \text{m}}{\text{ly}} \times \frac{\text{km}}{1000\ \text{m}} = \text{one sig. fig}$$

$700 = 7 \times 10^2$

$700. = 7.00 \times 10^2$ three sig. fig.

BOSTON UNIVERSITY

28

28

Time, distance, and speed

Google says the speed of light (in a vacuum) is 299 792 458 m/s.

Google says the star Betelgeuse is 700 ly (light years) from Earth.

How far away is Betelgeuse, in km (kilometers)?

$$1\ \text{ly} = \frac{299792458\ \text{m}}{\text{s}} \times \frac{3600\ \text{s}}{\text{hr}} \times \frac{24\ \text{hr}}{\text{day}} \times \frac{365.25\ \text{day}}{\text{yr}}\ \text{yr} = 9.4607 \times 10^{15}\ \text{m}$$

$$\text{distance} = 700\ \text{ly} \times \frac{9.4607 \times 10^{15}\ \text{m}}{\text{ly}} \times \frac{\text{km}}{1000\ \text{m}} = 7 \times 10^{15}\ \text{km}$$

BOSTON UNIVERSITY

29

29

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

0%	1.	2.88398
7%	2.	2.8840
57%	3.	2.884
7%	4.	2.9
29%	5.	3
0%	6.	2

930185

14 of 15

0

BOSTON UNIVERSITY

30

30

Significant figures

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

$$394.9 - 392 = 395 - 392 = 3$$

394.9 − 392.? ⇒ 395 − 392 = 3

BOSTON UNIVERSITY

31

31

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, 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	6	7	8	9
B Boron 10.81	C Carbon 12.0107	N Nitrogen 14.0067	O Oxygen 15.9994	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

35

[TP] What is the molecular mass of CS_2?

0% 1. 32.065
7% 2. 44.076
93% 3. 76.141
0% 4. Something else

5	6	7	8	9
B Boron 10.81	C Carbon 12.0107	N Nitrogen 14.0067	O Oxygen 15.9994	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

CS CS_2

12.0107 → 12.011
32.065 → 32.065
32.065 → 32.065

930185

15 of 15 0

BOSTON UNIVERSITY

36

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

0% 1. 46.7%
7% 2. 53.3%
93% 3. 69.6%
0% 4. 30.4%

5	6	7	8	9
B Boron 10.81	C Carbon 12.0107	N Nitrogen 14.0067	O Oxygen 15.9994	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

$\frac{O}{O + N}$

$\frac{\text{mass of O}}{\text{mass of } NO_2} * 100\%$

$\frac{2 * 15.9994}{14.0067 + 2 * 15.9994} * 100\%$

$\frac{2O}{N + 2O} =$

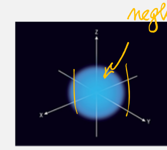
930185

15 of 15 0

BOSTON UNIVERSITY

38

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

43

Lecture 1 CH131 Summer 1 2021

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 44

44

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 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.

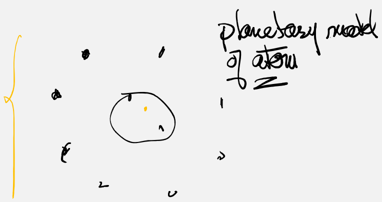
BOSTON UNIVERSITY 45

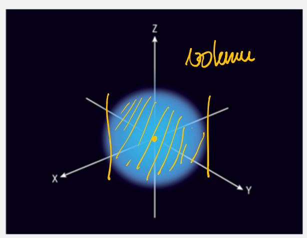
45

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 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.





BOSTON UNIVERSITY 46

46

Lecture 1 CH131 Summer 1 2021 Copyright © 2021 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
0%	2.	(34.969 + 36.966)/2
100%	3.	0.7578 × 34.969 + (1 − 0.7578) × 36.966
0%	4.	36.966
0%	5.	Something else

= 35.453

14 of 15

BOSTON UNIVERSITY 48

48

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

- 0% 1. $^{24}_{12}$Mg
- 14% 2. $^{26}_{12}$Mg
- 86% 3. More information needed

12
Mg
Magnesium
24.3050

930185

14 of 15

0

BOSTON UNIVERSITY

49

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

0.7899
0.1000
0.1101
1.0000

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

$f_{24} = 0.7899$, etc.

BOSTON UNIVERSITY

50

50

Element identity and atomic number Z

sodium
22.98976928
19
K
potassium
39.0983
37

$f_1 M_1 + f_2 M_2 + \ldots$

Number of protons = atomic number Z = 19

Relative atomic weight = 39.0983

Where does the number 39.0983 come from?

BOSTON UNIVERSITY

52

52

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.

sodium
22.98976928
19
K
potassium
39.0983
37

BOSTON UNIVERSITY

53

53

Atomic mass unit u

One ^{12}C atoms has mass 12 u

(1) 1 u = the mass of 1/12 of one ^{12}C atom.

(2) Exactly 12 g of ^{12}C is a lot of atoms. Really small.

$6.02214076 \times 10^{23}$ atoms = Avogadro's number

Reference atom is one atom of $^{12}_{6}C$. How much mass?

12 atomic mass unit

BOSTON UNIVERSITY 54

54

Atomic mass unit u

$^{12}C \equiv 12$ u

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

✓ Exactly 12 g of ^{12}C contains $N_A = 6.02214076 \times 10^{23}$ 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

$\frac{1}{12}\left(\frac{12\ g}{N_A}\right) = \frac{g}{N_A}$

BOSTON UNIVERSITY 55

55

Average mass of an atom of K

Two isotopes: K-39 and K-41

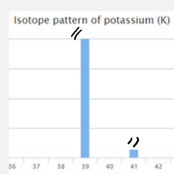
K-39 peak at 38.9637 u, height 933

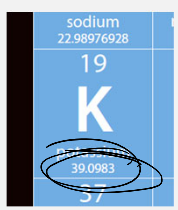
K-41 peak at 40.9618 u, height 67

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

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

$f_{39} = \frac{933}{933+67}$ $f_{41} = \frac{67}{933+67}$





BOSTON UNIVERSITY 56

56

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

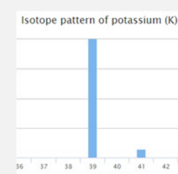
The average mass in g of an atom of K is

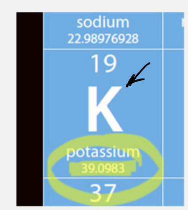
$= 39.098$ u

$= 39.098 \times (1/12) \times 12\ g \times (1/N_A)$

$= 39.098\ g / N_A$

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





BOSTON UNIVERSITY 57

57

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 58

58

Lecture 1 CH131 Summer 1 2021

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 59

59

