Measurement Book 3

February 22, 2019 11:10 AM

Chemistry 11

Unit 2: Introduction to Chemistry

Book 3: Significant Figures & Density

Name: Key Block:____

A. SIGNIFICANT FIGURES

When determining the correct value indicated by a measuring device, you should always record all of the s ignificant f igure (sometimes called "sig figs").

The number of **significant figures** in a measurement includes... all of the certain digits (numbered increments) PLUS the uncertain digit (estimate of the smallest increment)

- When a property such as mass, time, volume or length is measured you can ***never*** find the exact value.
- All measurements have a certian amoutn of uncertainty associated with them.
- the estimated, or uncertain digit is the ***last significant digit***.
- It determines how many significant figures a measure can have based on the accuracy of the measuring device. ← depends on the size of smallest increment

A significant figure is a **measured** or **meaningful digit**

c un.

Example: *if a stopwatch is used to time an event and the elapsed time is 35.2 s, then the measurement has* 3 *significant figures (* 3 *,* 5 *and* 2 *). If the stopwatch can only be read to 0.1 s then it is silly to claim that the time according to teh stopwatch is 35.2168497 s. Since the stopwatch cannot measure the time to 7 decimal places, the last digits (* 168497 *) have* NO significance*...in other words they are "fictional" or "imagined".* too much of an estimate.

Example: *if a balance gives a reading of 97.53 g when a beaker is placed on it. This first reading has* 4 *sig. figs. The beaker is then put on a different balance, giving a reading of 97.5295 g. In this second case there are now* 6 *sig. figs. because the measurement tool used, and the measurement taken has less uncertainly and likely, more precision.* = more sig. figs.

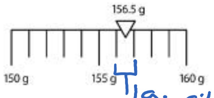


Figure 1.3.3 *Scale on a measuring device*

1g. 10% = ±0.1g

Say the scale on a measuring device reads as shown in Figure 1.3.3. (Note that *scale* may refer to the numerical increments on any measuring device.)

The measured value has 3 *certain figures* (1 , 5 , 6) and 1 *uncertain* figure (5 ±0.1g.).

Hence the measurement has 4 *significant figures.*

156.5g

certain

uncertain digit.

The following RULES. can be applied to determine how many figures are significant in any measurement.

RULES: Counting Significant Figures in a Measured Value

1. All non-zero digits are significant. eg. 156.4 4sf. 150 2sf.
2. All zeros between non-zero digits ARE significant. Such zeros may be called sandwiched or captive zeros. eg. 1004 4sf. 1400 2sf.
3. Leading zeros (zeros to the left of a non-zero digit) are ***never*** significant. eg. ~~0.000~~123 3sf.
4. Trailing zeros (zeros to the right of a non-zero digit) are only significant if there is a decimal in the number. 100 = 1sf. 100.0000

- Another way to determine the number of significant figures in a measured value is to simply express the number in scientific notation and count the digits. 0.000123 3sf. => 1.23 × 10^{-4} 3 sf.
- This method nicely eliminates the non-significant leading zeros.
- However, it is only successful if you recognize when to include the trailing (right side) zeros.
- Remember that trailing zeros are only significant if there is a decimal in the number.
- If the trailing zeros are significant, they need to be included when the number is written in scientific notation

eg. 100.0000

1×10^2 → 100

1.000000×10^2 → 100.0000

Sample Problems — Counting Significant Figures in a Measured Value

Determine the number of significant figures in each example.

1. 0.09204 g 2. 87.050 L

What to Think about

Question 1

1. To begin with, apply rule 3: leading zeros are never significant. Note that the position of the zero relative to the decimal is irrelevant. These are sometimes referred to as *place holding* zeros.
   The underlined leading zeros are not significant.
2. Apply rule 1 next: all non-zero digits are significant. The underlined digits are significant.
3. Finally, apply rule 2: the captive zero is significant. The underlined zero is sandwiched between two non-zero digits so it is significant.
4. A check of the number in scientific notation, 9.204×10^{-2} g, also shows four significant figures.

Question 2

1. Apply rule 1: all non-zero digits are significant. All of the underlined digits are significant.
2. Apply rule 2: the captive zero is significant. The underlined zero is between two non-zero digits so it is significant.
3. Finally, consider the trailing or right-side zero. Rule four states that such zeros are only significant if a decimal is present in the number. Note that the position of the zero relative to the decimal is irrelevant. As this number does contain a decimal, the underlined trailing zero is significant.
4. Check: 8.7050×10^{1} L has five sig figs (note that the right-side zero is retained).

How to Do It

leading zeros ✗

non-zeros ✓

0.09204 g

sandwich zero ✓

How many sig figs? 4

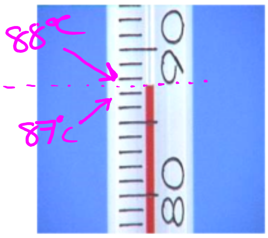
non-zeros ✓

trailing zero ✓ b/c of decimal

87.050 L

sandwich zero ✓

How many sig figs? 5



The image here shows a reading on a properly calibrated thermometer. We see with certainty that the temperature is between 87 °C and 88 °C. We are not certain, however, about the next decimal place.

The temperature *might* be read as 87.6 °C *or* 87.7 °C. ± 0.1 °C

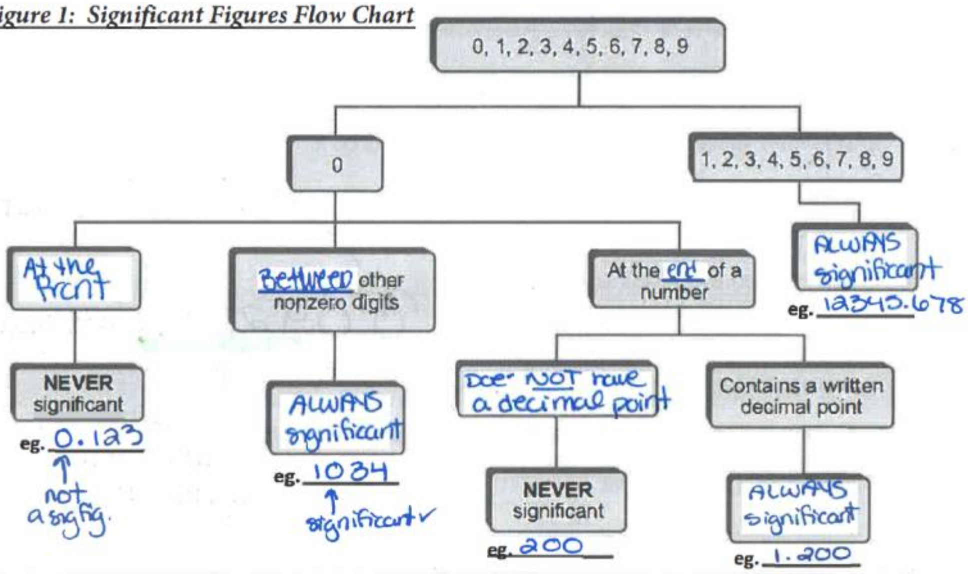
Thus, this measurement has two certain digits and one uncertain digit. 2 + 1 = 3

Therefore the measurement has 3 significant figures.

> Any measured number is characterized by the number of ***significant figures*** it contains.
>
> All of the significant figures in a measurement are certain digits except the last one.

③

Figure 1: Significant Figures Flow Chart



PRACTICE Counting Significant Figures in a Measured Value

Practice Problems — Counting Significant Figures in a Measured Value

1. How many significant figures are in each of the following measured values?

(a) 425 mL 3

(b) 590.50 g 5

(c) 0.00750 s 3

(d) 1.50×10^4 L 3

(e) 3400 m 2

2. Round the following measurements to the stated number of significant figures.

(a) 30.54 s (3 sig figs) 30.5 s

(b) 0.2895 g (3 sig figs) 0.290 g

(c) 4.49 m (2 sig figs) 4.5 m

(d) 100.4°C (2 sig figs) 1.0×10^2 °C

HW

Remember!

- An **ACCURATE** measurement is a measurement that is close to the CORRECT or ACCEPTED true value.
- A PRECISE measurement is a reproducible measurement. In general, the more precise a measurement, the MORE SIGNIFICANT DIGITS it has.

Example: *Assume that the correct witdth of the room is 5.32000m*

- a measurement of 5.3m is accurate *but not very* precise*. The value is close to the true value, but there are* ***not many significant figures*** *so the value is* ***not*** *very precise.*

-if ***several*** *measurements with some device consistently give the width as 5.45217m the measurements are* precise *but not* accurate*. (none of the sig figs are correct, so lacks accuracy)*

- If several measurements are given at 5.32001m, it is accurate *and* precise*.* ④

Assignment #9- Hebden pg 28-29 Questions #42-45
All assignments are to be completed on a separate page with the assignment number & heading. Be sure to show FULL WORKING OUT for all homework.

The number of ***significant figures*** is equal to ***all*** certain digits
PLUS the first uncertain digit

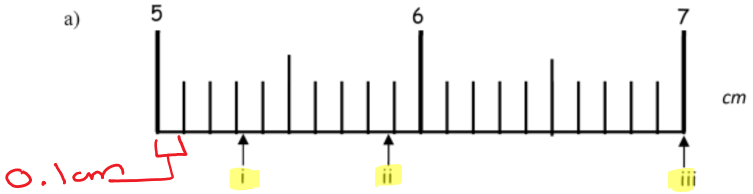
When making a measurement, the value you read from the measuring device contains *certain* digits (certain because they fall between ***divisions*** on the scale of the device) and a final *uncertain* digit (uncertain because it lies within the smallest division – forcing you to estimate its value).

We generally try to estimate to the ***nearest tenth*** of the value of the ***smallest division*** on the scale.

$$\text{Value of the smallest division} = \frac{\text{The difference between numbered divisions}}{\text{\# subdivisions between the numbers}}$$

uncertainty
10% of smallest increment.

a)



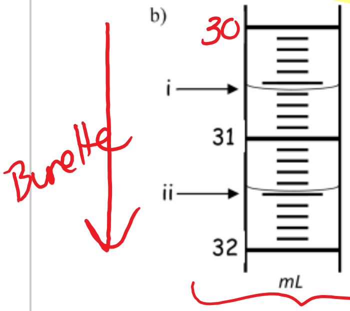
When a measurement falls directly on a number, the precision must be determined by examining the precision of the scale.

i) 5.32cm ii) 5.88cm iii) 7.00cm

Comment: ±0.01cm

5.88
certain + uncertain = all sig. figs!

b)

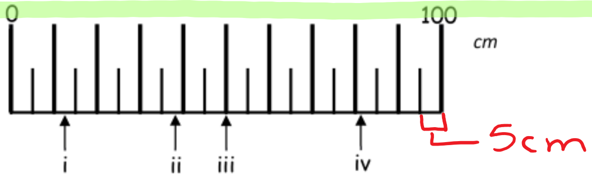


±0.01mL

i 30.54mL

ii 31.49mL

c)



i 13.0cm ii 38.5cm iii 50.0cm iv 81.0cm

Comment: ±0.5cm

Defined values or "counting" numbers are assumed to be **PERFECT** so they DO NOT count towards significant figures. This includes conversion factors

Example 1 When measuring the number of students in the class, there are *exactly* 18
There are no fractions, or decimals for "counting numbers".

~~2 s.f.~~

Example 2 The mass 32.5 kg has 3 significant figures.

Use a conversion factor 10^3 g = 1 kg to express the number in grams:

$$\underset{3\text{ sf.}}{32.5\text{ kg}} \times \boxed{\frac{10^3\text{ g}}{1\text{ kg}}} = \underset{3\text{ sf.}}{32\,500\text{ g}} = (3.25 \times 10^4\text{ g})$$

- You have NOT done another measurement.
- Which means there was no possible way for you to be more, or less precise.
- If ***precision has not changed***, the number of ***significant digits* does not change.**
- the mass of 32 500 g contains ***trailing zeros*** which are NOT significant.

The number of leading (or trailing) zeros depends on the size of the unit used to express the measured value, and it is ***not related*** to the precision, accuracy or number of significant figures.

Assignment #10- Hebden pg 29 + 37 Questions #46-47 + 55
All assignments are to be completed on a separate page with the assignment number & heading. Be sure to show FULL WORKING OUT for all homework.

B. OPERATIONS WTIH SIGNIFICANT FIGRUES

(×) (÷) sig. figs.

Rule 1 ***When you multiply or divide two measured values the result will have the same number of ______ as the one with the fewest number of significant figures.***

answer

"Least overall"

(+) (−)

Rule 2 ***When you add or subtract two measured values, the result will have the same number of decimal places as the one with the fewest number of decimal places***

"Least precise"

6

RULE #1 — Multiplication and Division with Significant Figures The answer to a multiplication or division problem should have only as many figures as the number having the Least *significant digits* in the problem.

Sample Problems — Significant Figures in Multiplication and Division Calculations

Give the answer to each of the following problems with the correct number of significant figures:

1. 8.2 m × 9.47 m =
2. 12 970.0 g ÷ 530.8 mL =

What to Think about

Question 1

1. Begin by applying rules 1 to 4 to determine the number of significant figures contained in each number in the problem.
2. Express the answer should be expressed to *two* significant figures.

Question 2

1. The second example involves more difficult numbers. Apply rules 1 to 4 to quickly determine the number of sig figs in each value.
2. Express the answer to *four* significant figures.

How to Do It

round to 2 sf.

$$\underbrace{8.2\,m}_{2\,s.f.} \times \underbrace{9.47}_{3\,sf.}m = \underbrace{77.654}_{2.\,sf.}\,m^2$$

least overall

$$\boxed{= 78\,m^2}$$

$$\frac{\overbrace{12\,970.0}^{6\,sf.}\,g}{\underbrace{530.8}_{4\,sf.}\,mL} = \underbrace{24.43481\ldots\ldots}_{4\,s.f.}$$

$$\boxed{= 24.43\ g/mL}$$

PRACTICE Give the answer to each of the following problems with the appropriate unit and the correct number of significant figures:

Problem 1 $\underbrace{57.320\ m}_{5\,s.f} \times \underbrace{12.43\ m}_{4\,sf.}$ $= \underset{(4\,sf.)}{\underline{712.5\,m^2}}$

Problem 2 1325.71 ~~L~~ ÷ $\underbrace{48.6}_{3\,sf.}$ ~~L~~ $= 27.3$

Problem 3 $\underbrace{0.054\ g}_{2\,sf.}$ ÷ 1.10 s $= \underbrace{0.049}_{2\,sf.}\ g/s$ (or $\underbrace{4.9}_{2\,sf.} \times 10^{-2}\ g/s$)

IMPORTANT: YOU MUST **ALWAYS** PERFORM CALCULATIONS TO THE MAXIMUM NUMBER OF SIGNIFICANT FIGURES ALLOWED BY YOUR CALCULATOR AND **ONLY** YOUR FINAL ANSWER SHOULD BE ROUNDED OFF TO THE CORRECT NUMBER OF SIGNIFICANT FIGURES. ROUNDING OFF **INTERMEDIATE** ANSWERS OFTEN PRODUCES INCORRECT RESULTS.

If you cannot keep all your calculated values in your calculator (or its memory), then always round off intermediate results so as to keep at least ONE "SIGNIFICANT FIGURE" more than you will eventually use in your final result.

RULE #2– Addition and Subtraction with Significant Figures

The answer to an addition or subtraction problem should have only as many figures as the ① Least Precise (least exact) number in the problem. (fewest decimal places)

The number of significant figures in the answer is determined by considering the ② Place Value of the last significant figure in each number in the problem.

(If both measurements include numbers to the right of a decimal, this means you simply round to the smallest number of decimal places.)

Sample Problems — Significant Figures in Addition and Subtraction Calculations

Give the answer to each of the following problems with the correct number of significant figures:

1. 246.812 cm + 1.3 cm =
2. 25 510 km − 7 000 km =

What to Think about

Question 1

1. In addition and subtraction problems, the most important thing is to determine the *place value* of the last significant figure in each number. 246.812 contains non-zero digits only, so the last significant figure is the last 2, which occupies the thousandths place.
   The 3 in 1.3 is the last significant figure and occupies the tenths place.
2. When these two place values are compared, the tenths is *less precise*; that is, it is *less exact* than the thousandths place. Round the final answer to the tenths place, resulting in a number with **four** significant figures. Notice that this rounded to one decimal place.

only precise to "thousands"

Question 2

1. The problem involves adding and subtracting. Determine the place value of the last significant figure in each number.
   The last significant figure in 25 510 is the 1. It is in the tens place. The 7 is the last significant figure in 7000. It is in the thousands place.
2. Thousands are far less exact than tens so round the final answer to the thousands place resulting in an answer with two significant figures. Notice that the decimal place simplification does not apply in this example.

How to Do It

246.812 cm
\+ 1.3 cm
least precise measure.

248.1 ~~12~~
don't care / not sig.

= 248.1 cm
(4 s.f.)

least precise "tens"

25 510 km
− 7 000 km
18 510 km

answer can only be precise to the "thousands" place value

= 19 000 km
(2 s.f)

PRACTICE

Give the answer to each of the following problems with the appropriate unit and the correct number of significant figures:

Problem 1 32.875 mL + 18.00381 mL

least precise (3 d.p).

= 50.87881mL

= 50.879mL

Problem 2 0.1510 g − 0.00817 g

least precise (4 d.p)

= 0.14283g

= 0.1428g

When combining operations, DO NOT round or truncate until you reach the final answer.

(otherwise you will introduce Rounding Errors into your answer!)

-½ re. -½ s.f ☹

Example 1: $\left[\dfrac{(57.1158\text{ kg} + 130.270\text{ kg} + 78.145\text{ kg})}{(15.8821\text{ s} - 7.123\text{ s})}\right]$

4dp. 3dp. 3dp.

4dp. 3dp.

$$= \frac{265.5308\text{ kg.}}{8.7591\ldots\text{s.}}$$

6 s.f.

4 s.f

"least overall"

$$= 30.3148\ldots\text{kg/s}$$

$$\boxed{= 30.31\text{ kg/s}}$$

Special Case: Numbers in Scientific Notation

(only for ⊕ ⊖)

Example 2 $0.\ 8.1175 \times 10^{\cancel{-10}\,-9}\text{ g} + 3.0035 \times 10^{-9}\text{ g}$

"left larger"

4dp 4dp.

$$\begin{array}{r} 0.81175 \times 10^{-9} \\ +\ 3.0035 \times 10^{-9} \\ \hline 3.8152\cancel{5} \times 10^{-9} \end{array}$$

$$\boxed{= 3.8153 \times 10^{-9}\text{ g}}$$

Example 2 $2.1753 \times 10^{500} - 5.783 \times 10^{\cancel{499}\,500}$

4dp. 3dp.

$$\begin{array}{r} 2.1753 \times 10^{500} \\ -\ 0.5783 \times 10^{500} \\ \hline \boxed{1.5970 \times 10^{500}} \end{array}$$

least precise is 4 dp.

Assignment #11- Hebden pg 39-40 Questions #56-58

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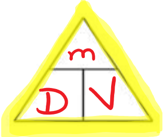
C. DENSITY

The density, or more precisely, the volumetric mass density, of a substance is its mass per unit volume.
The symbol most often used for density is ρ *(the lower case Greek letter rho)*, although the Latin letter D can also be used.

Mass = the quantity of matter
Volume = the mass contained in a given space

In other words, density is mass divided by volume.

$D = \rho = \frac{m}{V}$



If mass "m" is measured in (g),
and volume "V" is measured in (L)

What are the units for density? g/L
(g/mL)

EXAMPLE: An iron bar has a mass of 19 600 g and a volume of 2.50 L. What is the iron's density?

$D = \frac{m}{V} = \frac{19\,600\,g}{2.50\,L} = 7\,840\,g/L$ (or $7.84 \times 10^3\,g/L$)

EXAMPLE: If mercury has a density of 13 600 g/L, what volume (in millilitres) is occupied by 425g of mercury? mL

$D = \frac{m}{V} \therefore V = \frac{m}{D} = \frac{425\cancel{g}}{13\,600\,\cancel{g}/L} = 0.03125\cancel{L} \times \frac{1\,mL}{10^{-3}\cancel{L}} = 0.03125 \times 10^3\,mL$

$= 31.2\cancel{5}\,mL$

$\boxed{= 31.3\,mL}$

IMPORTANT FACT:

For water at 4oC –
d = 1000.0 g/L
or **d = 1.0000 g/mL**

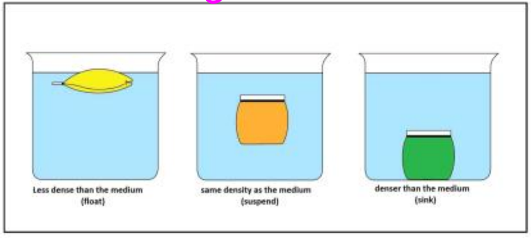
Measurig the volume of a sample of water allows you to immediately know its mass, and vice versa.

Density can be tranlated into a conversion statement:

1g = 1mL (for water)

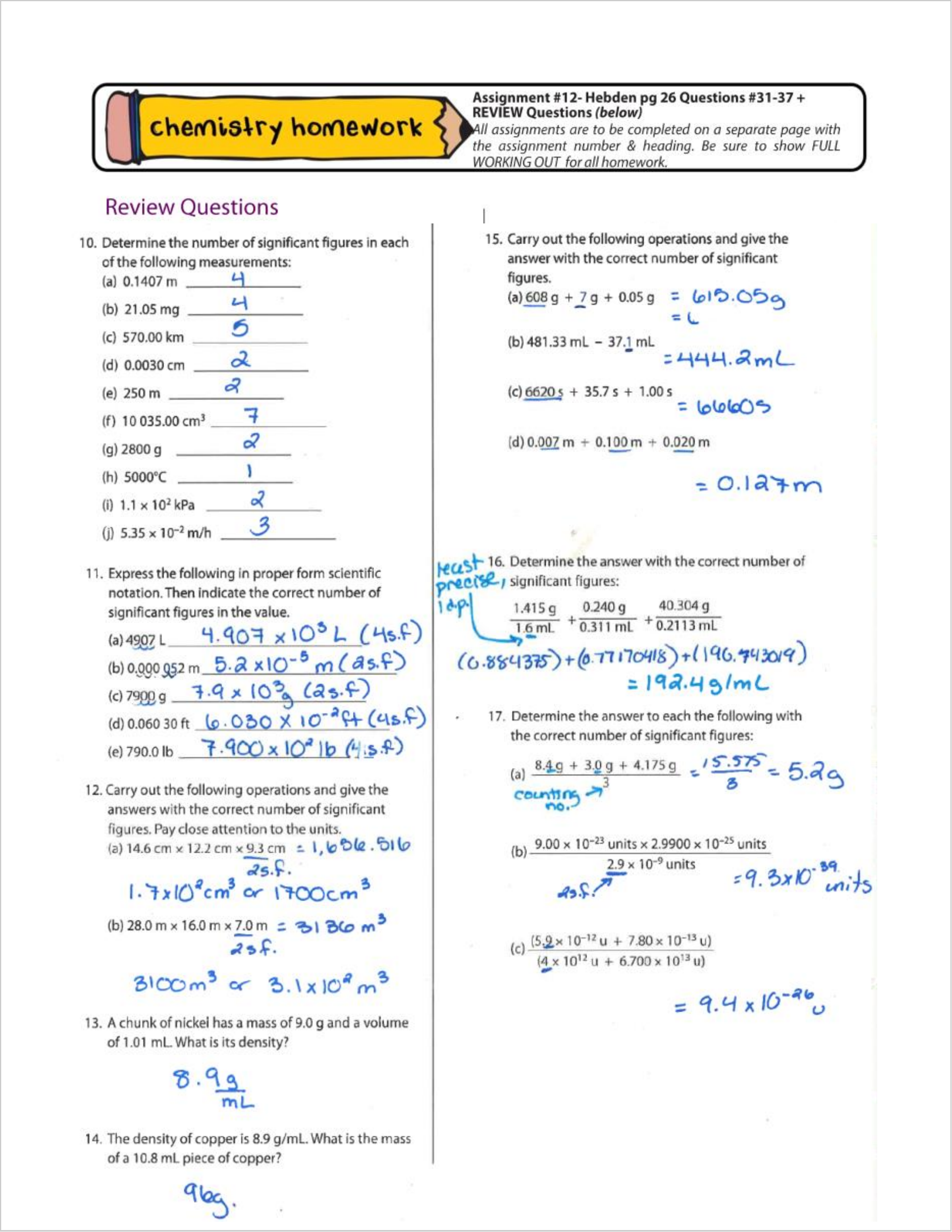
IMPORTANT FACT:

Less dense liquids and objects Float on liquids having a greater density.



Objects will sink in a liquid if
$d_{OBJECT} > d_{LIQUID}$.

Objects will float in a liquid if
$d_{OBJECT} < d_{LIQUID}$.



chemistry homework

Assignment #12- Hebden pg 26 Questions #31-37 +
REVIEW Questions *(below)*
All assignments are to be completed on a separate page with the assignment number & heading. Be sure to show FULL WORKING OUT for all homework.

Review Questions

10. Determine the number of significant figures in each of the following measurements:

(a) 0.1407 m 4
(b) 21.05 mg 4
(c) 570.00 km 5
(d) 0.0030 cm 2
(e) 250 m 2
(f) 10 035.00 cm^3 7
(g) 2800 g 2
(h) 5000°C 1
(i) 1.1×10^2 kPa 2
(j) 5.35×10^{-2} m/h 3

11. Express the following in proper form scientific notation. Then indicate the correct number of significant figures in the value.

(a) 4907 L 4.907×10^3 L (4s.f)
(b) 0.000 052 m 5.2×10^{-5} m (2s.f)
(c) 7900 g 7.9×10^3 g (2s.f)
(d) 0.060 30 ft 6.030×10^{-2} ft (4s.f)
(e) 790.0 lb 7.900×10^2 lb (4s.f)

12. Carry out the following operations and give the answers with the correct number of significant figures. Pay close attention to the units.

(a) 14.6 cm × 12.2 cm × $\underbrace{9.3\text{ cm}}_{2s.f.}$ = 1,656.516

$1.7\times10^{2}cm^{3}$ or $1700cm^{3}$

(b) 28.0 m × 16.0 m × $\underbrace{7.0\text{ m}}_{2sf.}$ = 3136 m^3

$3100m^{3}$ or $3.1\times10^{2}m^{3}$

13. A chunk of nickel has a mass of 9.0 g and a volume of 1.01 mL. What is its density?

$8.9\frac{g}{mL}$

14. The density of copper is 8.9 g/mL. What is the mass of a 10.8 mL piece of copper?

96g.

15. Carry out the following operations and give the answer with the correct number of significant figures.

(a) 608 g + 7 g + 0.05 g = 615.05g
= 6

(b) 481.33 mL − 37.1 mL =444.2mL

(c) 6620 s + 35.7 s + 1.00 s = 6660s

(d) 0.007 m + 0.100 m + 0.020 m

= 0.127m

16. Determine the answer with the correct number of significant figures:

least precise, 1d.p.

$$\frac{1.415\text{ g}}{1.6\text{ mL}} + \frac{0.240\text{ g}}{0.311\text{ mL}} + \frac{40.304\text{ g}}{0.2113\text{ mL}}$$

(0.884375)+(0.77170418)+(190.743019)
= 192.4g/mL

17. Determine the answer to each the following with the correct number of significant figures:

(a) $$\frac{8.4\text{ g} + 3.0\text{ g} + 4.175\text{ g}}{3} = \frac{15.575}{3} = 5.2g$$

counting no.

(b) $$\frac{9.00 \times 10^{-23}\text{ units} \times 2.9900 \times 10^{-25}\text{ units}}{2.9 \times 10^{-9}\text{ units}}$$

2s.f.

$=9.3\times10^{-39}$ units

(c) $$\frac{(5.2 \times 10^{-12}\text{ u} + 7.80 \times 10^{-13}\text{ u})}{(4 \times 10^{12}\text{ u} + 6.700 \times 10^{13}\text{ u})}$$

$= 9.4\times10^{-26}$ u