Name ____ Date __________ Period ___

Significant Figures (abbreviated sig figs)

A lever balance used to weigh a truckload of stone may be accurate to the nearest 100 kg, giving a reading of 15 200 kg, for instance. The measurement should be written in such a way that a person looking at it will understand that it represents the mass of the truck to the nearest 100 kg, that is, that the mass is somewhere between 15 100 kg and 15 300 kg.

Some laboratory balances are sensitive to differences of 0.001 g. Suppose you use such a balance to weigh 0.206 g of aluminum foil. A person looking at your data table should be able to see that the measurement was made on a balance that measures mass to the nearest 0.001 g. You should not state the measurement from the laboratory balance as 0.2060 g instead of 0.206 g because the balance was not sensitive enough to measure 0.0001 g.

To convey the accuracy of measurements, all people working in science use significant figures. A *significant figure is a digit that represents an actual measurement.* The mass of the truck was stated as 15 200 kg. The 1, 5, and 2 are significant figures because the balance was able to measure ten-thousands, thousand, and hundreds of kilograms. The truck balance was not sensitive enough to measure tens of kilograms or single kilograms. Therefore, the two zeros are not significant and the measurement has three significant figures. The mass of the foils was correctly stated as 0.206 g. There are three decimal places in this measurement that are know with some certainty. Therefore, this measurement has three significant digits. Had the mass been stated as 0.2060 g, a fourth significant figure would have been incorrectly implied.

Rules for Determining Significant Figures

A. All digits that are not zeros are significant.

All are nonzero digits

325 mL of ethanol
The measurement has three significant figures.

All are nonzero digits

1.325 g of zinc
The measurement has four significant figures

B. Zeros may or may not be significant. To determine whether a zero is significant, use the following rules.

1. Zeros appearing between nonzero digits are significant.

Nonzero digits

40.7 L of ammonia
The measurement has three significant figures

Nonzero digits

32 006 m of wire
The measurement has five significant figures

2. Zeros appearing in front of nonzero digits (also called leading zeros) are not significant.

Nonzero digits

0.0572 m^2 of foil
The measurement has three significant figures

Nonzero digits

0.000 2 g of RNA
The measurement has has one significant figure

3. Zeros at the end of a number and to the right of a decimal are significant figures. Zeros between nonzero digits and significant zeros are also significant. This is a restatement of Rule 1.

Nonzero digits	**Nonzero digits**
97.00 kg of tungsten	1200.00 cm^3 of lead
Zeros to the right of a number and after a decimal point	**Zeros to the right of a number and after a decimal point**
The measurement has four significant figures	*The measurement has has six significant figures.*

4. Zeros at the end of a number but to the left of a decimal may or may not be significant. If such a zero has been measured or is the first estimated digit, it is significant. On the other hand, if the zero has not been measured or estimated but is just a place holder, it is not significant. ***A decimal placed after the zeros indicates that they are significant.***

Nonzero digits	**Nonzero digits**
3400 g of sulfur	4000. mL of oxygen
The measurement has two significant figures	**Decimal point is present, so these zeros are significant.**
	The measurement has four significant digits.

The rules are summarized in the following flowchart:

Look for nonzero digits – all of them are significant

↓

Look for zeros between nonzero digits – they are significant.

↓

Look for a decimal point

There <u>is</u> a decimal point → **Look for zeros at the end of the number – they are significant. Leading zeros for decimal numbers less than one are NOT.** → **Total up the number of significant figures.**

There is <u>no</u> decimal point. → **Total up the number of significant figures.**

Directions: Complete the following problems being sure to follow the rules of significant digits.

1. Determine the number of significant digits in the following measurements:

A. 980 cm^3	_______	F. 30.700 cm	_______
B. 900.0 mL	_______	G. 0.000 000 25 g/L	_______
C. 0.3200 g	_______	H. 0.080 01 kg/m^3	_______
D. 5.005 kg	_______	I. 250 008 cm^2	_______
E. 60 000 L	_______	J. 456.000 kg*m/s^2	_______

Determining Significant Figures in Calculations

Suppose you want to determine the density of an ethanol-water solution. You first measure the volume in a graduated cylinder that is accurate to the nearest 0.1 mL. You then determine the mass of the solution on a balance that can measure mass to the nearest 0.001 g. You have read each measuring device as accurately as you can, and you record the following data:

MEASUREMENT	DATA
Mass of solution, m	11.079 g
Volume of solution, V	12.7 mL
Density of solution in g/mL,D	???

You can determine density on your calculator and get the following result:

D = m/V = 11.079 g/12.7 mL = 0.872 362 204 g/mL

Although the numbers divide out to give the result shown, it is not correct to say that this quantity is the density of the solution. Remember that you are dealing with measurements, not just numbers. Consider the fact that you measured the mass of the solution with a balance that gave a reading with five significant figures: 11.079 g. In addition, you measured the volume of the solution with a graduated cylinder that was readable only to three significant figures: 12.7 mL. It seems odd to claim that you now know the density with an accuracy of nine significant figures.

You can calculate the density – or any measurement – *only as accurately as the <u>least accurate</u> measurement* that was used in the calculation. In this case the least accurate measurement was the volume because the measuring device you used was capable of giving you a measurement with only three significant figures. Therefore, you can state the density to only three significant figures.

Rules for Calculating with Measured Quantities

Operation	Rule
Multiplication and division	Round off the calculated result to the same number of significant figures as the measurement having the fewest significant figures.
Addition and subtraction	Round off the calculated result to the same number of decimal places as the measurement with the fewest decimal places. If there is no decimal point, round the result back to the digit that is in the same position as the leftmost uncertain digit in the quantities being added or subtracted.

In the previous example, you must round off your calculator reading to a value that contains three significant figures. In this case you would say:

$$D = m/V = 11.079\ g/12.7\ mL = 0.872\ \cancel{362\ 204}\ g/mL = 0.872\ g/mL$$

Directions: Perform the following calculations, and express the result in the correct units and number of significant digits. **Follow all rounding rules (see Table 2-6 on p. 48 of your textbook). SHOW ALL UNITS!!!!!!**

2. A. 87.0 m ÷ 9.2 s ________
   B. 890 cm x 22 cm ________
   C. 9.88 kg ÷ 200 ________
   D. 0.00 80 m^2 x 0.022 m ________
   E. 100.3 L ÷ 110. s ________
   F. 77.00 cm^2 x 6.70 cm ________
   G. 85 000 kJ ÷ 0.350 min ________

3. A. 44.0 m + 6.35 m + 11.5 m ________
   B. 0.022 kg + 1.888 kg + 0.503 kg ________
   C. 200 cm^2 + 9.5 cm^2 – 44 cm^2 ________
   D. 0.004 L + 0.0074 L + 0.300 L ________
   E. 96.50 dL + 3.40 dL + 20.1 dL ________
   F. 2300 mg + 523 mg – 886 mg ________
   G. 18 000 kg + 3000 kg + 950 kg ________

(These problems involve both factor labeling and significant digits, show your work on another sheet of paper and attach those to this handout when you turn it in!)

4. A rectangle measures 78.95 cm by 53.1 mm. Express its area with the proper number of significant figures in the specified unit:
   A. in cm^2

   B. in mm^2

   C. in m^2

5. A box measures 800. mm by 13.5 mm by 3.6 cm. State its volume with the proper number of significant digits in the specified unit:
   A. in cm^3

   B. in m^3

   C. in mm^3

6. A 160 mL sample of liquid has a mass of 0.61 kg. What is the density of the liquid in the following measurements?
   A. kg/m^3

   B. g/mL

   C. kg/dm^3

7. A water pipe fills a container that measures 179 cm x 303 cm x 252 cm in 87 s.
   A. What is the volume of the container in cubic meters?

   B. What is the rate of flow in the pipe in liters per minute?

   C. What is the rate of flow in cubic meters per hour?