Chem 1A
Chapter-1 Exercises (OpenStax)

PREFIXES AND SYMBOLS

SI Prefixes you need to know by heart

Prefix	Symbol	In 10^n	in Decimal Forms
Giga	G	10^9	1,000,000,000
Mega	M	10^6	1,000,000
kilo	k	10^3	1,000
deci	d	10^{-1}	0.1
centi	c	10^{-2}	0.01
milli	m	10^{-3}	0.001
micro	μ	10^{-6}	0.000,001
nano	n	10^{-9}	0.000,000,001
pico	p	10^{-12}	0.000,000,000,001

SI Base Units

Mass =	kilogram (kg)
Length =	meter (m)
Time =	second (s)
Temperature =	Kelvin (K)
Amount =	Mole (mol)
Current =	Ampere (A)
Intensity =	candela (ca)

SI Derived Units

Volume =	cubic meter (m^3)
Force =	Newton (N)
Energy =	Joule (J)
Power =	Watt (W)
Charge =	Coulomb (C)
Potential =	volt (V)
Resistance =	ohm (Ω)
Frequency =	Hertz (Hz)

Significant Figures

1. All non-zero digits are significant and must be counted.

   Example: 1234 has 4 significant figures

2. All *captive zeroes* are also significant;

   Example: 2305 has 4 significant figures

3. *Leading zeroes* are not significant and need not be counted;

   Example: 0.08205 has 4 significant figures

4. *Trailing zeroes* are significant digits only if the numerical values have decimal points, otherwise they are NOT significant figures.

   Examples: 25.00 has 4 significant figures, but 2,500 has 2 significant figures.
   2,400 has 2 significant figures, but 2.400 x 10^3 has 4 significant figures;
   2,400. also has 4 significant figures.

5. *Exact numbers* are values obtained by counting or given by definition. Such values have *unlimited significant figures* (it has zero uncertainty). For example, the number of apples in a basket is an exact number; 1 inch = 2.54 cm is also an exact number and implies unlimited significant figures.

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Rules for Determining Significant Figures and Rounding off in Calculations

1. In ***Multiplication*** and ***Divisions***, the answer should have the same number of significant figures as one with the least significant figures. Examples:

   a) 5.62 cm x 1.45 cm x **0.93** cm = 7.57857 cm^3, which is rounded off to <u>7.6 cm^3</u>

   b) $\frac{20.505 \text{ g}}{\mathbf{7.6} \text{ cm}^3}$ = 2.6980263 g/cm^3, rounded off to <u>2.7 g/cm^3</u>.

   c) $\frac{(3.60 \times 8.312)}{\mathbf{4.5}}$ = 6.6496, rounded off to <u>6.6</u>

2. In ***Addition*** and ***Subtraction***, the answer should have the same digits after the decimal as one with the least decimal places. (If any of the values has no decimal number, the answer should not have any decimal place also.)

   Examples: a) 12.11 + **18.0** - 1.013 = 29.097, which is rounded off to <u>29.1</u>

   b) 12.11 + **18** + 1.013 = 31.123 is rounded off to <u>31</u>

<u>Exercises #1:</u>

1. Determine the number of significant figures in each of the following quantities.

   (a) 0.00239 ________ (b) 0.01950 _________ (c) 1.07 x 10^{-3} ________

   (d) 1.0040 ________ (e) 48,000 _________ (f) 0.082059 ________

   (g) 93.00 ________ (h) 3.00 x 10^8 _________ (*i*) 120 eggs ________

2. Re-write the following decimal numbers in scientific notation without altering the number of significant figures.

   (a) 0.000548580 = _________________ (b) 48,000 = ________________

   (c) 200. = __________________ (d) 0.010050 = _______________

3. Re-write the following exponential numbers in the decimal forms, while maintaining the number of significant figures.

   (a) 3.982 x 10^5 = __________________ (b) 5.480 x 10^{-3} = ________________

   (c) 5.5 x 10^{-4} = _________________ (d) 6.235 x 10^4 = _________________

4. Round off the following quantities to the number of significant figures indicated in parenthesis.

   (a) 0.037421 (3) = ________________ (b) 1.5587 (2) = ________________

   (c) 29,979 (3) = __________________ (d) 201,035 (4) = _________________

5. Express the following quantities using the significant figures that are consistent with the precision (that would imply the state error).

   (a) 2.3 ± 0.001 = ________________ (b) 22,500 ± 10 = ________________

   (c) 21.45 ± 0.02 = _______________ (d) 0.00549 ± 0.0001 = ______________

6. Perform the following mathematical operations and report the answer to the proper number of significant figures.

   (a) 32.27 x 1.54 ÷ 0.07925 = _____________

   (b) 8.2198 + 0.253 – 5.32 = ______________

   (c) (8.52 + 4.1586) x (18.73 + 15.3) = ______________

   (d) 6.75 x 10^{-4} - 5.4 x 10^{-3} + 0.01953 = _____________

   (e) $$\frac{(6.626 \times 10^{-34}\ \text{J.s}) \times (2.9979 \times 10^{8}\ \text{m/s})}{5.50 \times 10^{-7}\ \text{m}}$$ = _______________ (give appropriate unit)

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Value Placement

Large Units	Normal	Small Units	very small Units
Kilogram (kg) 1,000 (10^3) g	Gram (g) 1 g	milligram (mg) 0.001 (10^{-3}) g	microgram (μg) 0.000,001 (10^{-6}) g
Kilometer (km) 1,000 (10^3) m	Meter (m) 1 m	millimeter 0.001 (10^{-3}) m	nanometer (μm) 0.000,000,001 (10^{-9}) m

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Unit Conversion and value equivalences:

(a) Conversion from a large unit to a small one results in a larger numerical quantity:
(the number gets larger)

Example: 1 km $\longrightarrow$ 10^3 m $\longrightarrow$ 10^5 cm $\longrightarrow$ 10^6 mm

(b) Conversion of a small unit to a larger one will results in numerical quantity to become smaller:
(note that the number gets smaller)

Example: 1 μg $\longrightarrow$ 10^{-3} mg $\longrightarrow$ 10^{-6} g $\longrightarrow$ 10^{-9} kg

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Exercises #2:

Units Conversion

1. What are the SI base or derived units for the following measurements? Write the names and abbreviations.

   Mass = __________; Length = ____________; Area = ______________

   Volume = _________; Density = ____________; Time = ________________

2. Metric unit conversions: fill in the blanks with appropriate values:

   1 km = ___________m; 1 m = ________cm; 1 cm = __________nm;

   1 g = ___________μg; 1 μg = _________kg; 1 m^3 = ___________cm^3;

3. American unit conversions: fill in the blanks with appropriate values:

   1 mi = ___________yd; 1 yd = ________ft; 1 ft = __________in;

   1 yd = ___________in; 1 lb = _________oz; ton = ___________lb;

   1 hr = ___________min; 1 hr = ___________s;

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4. Perform the following conversions:

   (a) Given: 1 yard = 36 inches; 1 inch = 2.54 cm (exactly), and 1 m = 100 cm.

   Convert 110. yards to meters and express your answer to three significant figures.

   (b) Given: 1 mile = 1760 yd, 1 yard = 0.9144 m, and 1 km = 1000 m.

   Convert 55 miles to kilometers and express your answer to two significant figures.

5. (a) The average price of gasoline in Japan is 150 ¥/L (JPY per liter). If 1 gallon = 3.7854 L and 1 USD = 124 JPY, what is the price of gasoline in Japan if paid in USD/gall?

   (b) The price of gold is $1,095 per ounce. How much does 96.5 g of gold worth in USD?
   (1 lb = 16 oz; 1 lb = 453.6 g)

   (c) The fuel tank of a Toyota Corolla has a capacity of 14.9 gallons. Express the fuel tank in cubic meters (m^3).
   (Given: 1 gallon = 3.7854 L; 1 L = 10^3 mL; 1 mL = 1 cm^3, and 1 m^3 = 10^6 cm^3)

6. Given: 1 foot = 12 inches; 1 inch = 2.54 cm, and 1 m = 100 cm, perform the following conversions:

   (a) 1 in^2 = ____________cm^2; (b) 1 in^3 = ____________cm^3;

   (c) 1 ft^2 = ____________m^2; (d) 1 ft^3 = ____________m^3.

7. If 1 mi = 1.609 km and 1 gall. = 3.7854 L, what is 35 mpg (miles per gallon) in kilometers per liter (km/L)?

8. The speed of light is 2.998 x 10^8 m/s (meters per second). What is the speed of light in miles per hour (mph)? (1 mi. = 1.609 km; 1 km = 10^3 m, and 1 hour = 3600 s)

Statistical Analysis

Mean, Median, and Standard Deviation

Suppose that you obtain a sample of 10 pennies, weigh them individually, and the following masses in grams were collected:

2.50, 2.49, 2.52, 2.51, 2.51, 2.50, 2.52, 2.50, 3.01, and 2.51 g

Note that, while most of the pennies weigh about 2.5 g, one of them weighs 3.01 g, which is significantly different from the rest of the pennies. This penny does not belong to the group and should not be included in the statistical analysis. Subsequently, the *mean*, *median*, and *standard deviation* should be derived from the remaining 9 pennies. The data may be tabulated as shown in the following table.

Penny #	Mass, g	$(X_i - \overline{X})$	$(X_i - \overline{X})^2$
1	2.50	-0.01	0.0001
2	2.49	-0.02	0.0004
3	2.52	0.01	0.0001
4	2.51	0.00	0.0000
5	2.51	0.00	0.0000
6	2.50	-0.01	0.0001
7	2.52	0.01	0.0001
8	2.50	-0.01	0.0001
9	2.51	0.00	0.0000
Sum =	22.56	0.07	0.0009

$$Mean = \frac{\text{Sum of masses}}{\text{No. of acceptable data}} = \frac{22.56\text{g}}{9} = 2.507 \text{ g}$$

The *standard deviation*: $S = \sqrt{\dfrac{\Sigma(X_i - \overline{X})^2}{(N - 1)}} = \sqrt{\dfrac{0.0009}{8}} = \mathbf{0.01}$

Then, the mean will be re-written as **2.51 ± 0.01 g**

[Note that, standard deviation should have ONE significant figure only, because it represents the *uncertainty* in the data. Since this *uncertainty* appears on the second decimal digit, the calculated mean must be rounded off to 2.51 to be consistent with the precision of the data.]

To obtain the *median* value, the data values may be re-arranged in increasing or decreasing order. The *median* value is the middle value (for odd number of data set) or the average of two middle values (for an even number of data set). In the following set of data, the *median* is **2.51**.

2.49, 2.50, 2.50, 2.50, 2.51, 2.51, 2.51, 2.52, 2.52

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Exercises #3:

1. The masses of three pennies obtained by direct weighing using three different balances are as follows: 2.51 g, 2.508 g, and 2.5078 g. (a) What is the total mass of the three pennies expressed in correct significant figures? (b) Calculate the average mass of pennies.

2. A student weighed 12 pennies on a balance and recorded the following masses:

3.112 g	3.109 g	3.059 g	2.518 g	3.079 g	3.129 g
3.081 g	2.504 g	3.050 g	3.072 g	3.064 g	3.131 g;

1) Are there outliers among the masses of pennies?
2) Calculate the mean mass of pennies and the standard deviation excluding the outliers. Write the mean mass with precision.

3. Three students used different balances to obtain the mass of the same object, in which each student weighed the object three times, and obtain the following results were obtained:

Weighing Trials	Student #1	Student #2	Student #3
1	16.015 g	15.414 g	14.893 g
2	16.002 g	15.430 g	14.902 g
3	15.980 g	15.450 g	14.896 g

(a) Calculate the average mass of the object determined by each student.

(b) Which student is the most precise and which student is the least precise?

(c) If the true mass of the object is 15.000 g, which student has the most accurate measurements?

(d) Describe the type of error that might have caused differences in the mass of the object obtained by each student.

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Exercises #4:

Density:

1. A cylindrical metal bar weighs 79.38 g. If the bar measures 8.50 cm long and has a diameter of 2.10 cm, what is the density of metal?

2. A wooden cylindrical rod weighs 24.95 g. The rod is 7.50 cm long and has a diameter of 2.16 cm. Determine whether the rod will float or sink in water (density = 1.00 g/mL).

3. A rectangular metal block has the following dimension: 36.0 cm long, 2.50 cm wide, and 1.00 cm thick. Calculate the mass of the metal bar if it is made of: (a) pure aluminum (density = 2.70 g/cm^3); (b) pure lead (density = 11.35 g/cm^3).

4. A flask weighs 64.25 g when empty and weighs 91.75 g when filled with water at 20°C. However, when the flask is filled with isopropyl alcohol at the same temperature, the combined mass of flask and alcohol is 85.90 g. If the density of water is 0.99823 g/mL at 20°C, determine the density of isopropyl alcohol at 20°C. (Assume that both water and isopropyl alcohol occupy the same volume.)

5. A rectangular sheet of copper with a uniform thickness measures 12.0 in. by 10.0 in. and weighs 936.50 grams. If the density of copper is 8.96 g/cm^3, calculate the thickness of the copper sheet in millimeter. (1 inch = 2.54 cm)

6. A 50-mL graduated cylinder weighs 41.30 g when empty. When filled with 30.0 mL of water, the combined mass is 71.25 g. A piece of metal is dropped into the water in cylinder, which causes the water level to increase to 36.9 mL. The combined mass of cylinder, water and metal is 132.65 g. Calculate the densities of water and metal, respectively.

Temperature Conversion:

7. Perform the following temperature conversions:

   (a) A temperature of 116°F to degrees Celsius (°C) and to Kelvin (K), respectively.

   (b) A temperature of 218 K to degrees Celsius (°C) and to degrees Fahrenheit (°C), respectively.

   (c) A temperature of -40.0°C to Kelvin and to °F, respectively.

8. The boiling point of liquid nitrogen is 77 K. What is the boiling point in degrees Celsius and in degrees Fahrenheit, respectively?

9. A T-scale thermometer is calibrated by setting the freezing point of water to –20°T and the boiling point of water to 230°T. If this thermometer records a temperature of 92.5°T, what is the temperature equivalent in degrees Celsius (°C) and in degrees Fahrenheit (°C), respectively?

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Answers:

Exercise #1:

1. (a) 3 (b) 4 (c) 3 (d) 5 (e) 2 (f) 5 (g) 4 (h) 3 (*i*) 3
2. (a) 5.48580×10^{-4} (b) 4.8×10^{4} (c) 2.00×10^{2} (d) 1.0050×10^{-2}
3. (a) 398,200 (b) 0.005480 (c) 0.00055 (d) 62,350
4. (a) 0.0374 (b) 1.6 (c) 3.00×10^{4} (d) 2.010×10^{5}
5. (a) 2.300 ± 0.001; (b) $2.250 \times 10^{4} \pm 10$; (c) 21.45 ± 0.02; (d) 0.0055 ± 0.0001
6. (a) 627 (b) 3.15 (c) 431 (d) 1.48×10^{-2} (e) 3.61×10^{-19} J

Exercise #2

1. Mass = kilogram (Kg); length = meter (m); Volume = cubic meter (m^3)
   Temperature = Kelvin (K) density = Kg/m^3 time = second (s)
2. 1 km = 1000 m; 1 m = 100 cm; 1 cm = 10^7 nm; 1 g = 10^6 □g; 1 □g = 10^{-9} kg; 1 m^3 = 10^6 cm^3;
3. 1 mi = 1760 yd; 1 yd = 3 ft; 1 ft = 12 in; 1 yd = 36 in; 1 lb = 16 oz; 1 ton = 2000 lb;
   1 hr = 60 min; 1 hr = 3600 s;
4. (a) 101 m; (b) 89 km;
5. (a) \$4.58 per gallon; (b) US\$3,727; (c) 0.0564 m^3;
   (c) (*i*) 1 in^2 = 6.45 cm^2; 1 in^3 = 16.4 cm^3 (*ii*) 1 ft^2 = 0.0929 m^2; 1 ft^3 = 0.0283 m^3
6. (a) 1 in^2 = 6.45 cm^2; (b) 1 in^3 = 16.4 cm^3; (c) 1 ft^2 = 0.0929 m^2; (d) 1 ft^3 = 0.0283 m^3.
7. 15 kmpL (kilometers per liter)
8. 6.71×10^{8} mph (miles per hour)

Exercise #3:

1. (a) 7.53 g; (b) 2.51 g;
2. (a) outliers = 2.518 g & 2.504 g; (b) mean with precision = 3.09 ± 0.03 g; std. deviation = 0.03 g
3. (a) Average mass: Student#1 = 15.999 g; Student#2 = 15.431 g; Student#3 = 14.897 g;
   (b) Most precise: Student#3 (lowest % deviation); least precise: student#2 (largest % deviation;
   (c) Most accurate: Student#3 (lowest percent error = 0.687%)
   (d) Balances used by student#1 and student#2 most probably has systematic error – all measurements are quite precise, but the balances consistently give masses that are higher than the true value.

Exercise #4:

1. density of metal bar = 2.70 g/cm^3;
2. Density of rod = 0.908 g/cm^3; it will float on water;
3. (a) mass of aluminum block = 243 g; (b) mass of lead block = 1.02×10^{3} g
4. density of alcohol = 0.786 g/mL;
5. Thickness of copper sheet = 0.135 cm (or 1.35 mm);
6. density of water = 0.998 g/mL; density of metal = 8.9 g/mL;
7. (a) 313.2 K; (b) -175°F; (c) -40°C
8. Boiling point of N_2 = -196°C = -321°F;
9. 45°C; 113°F