Objective 1. Scientific measurement – represent uncertainty in measurement and calculations using sig figs, apply dimensional analysis (factor-label method) in conversions and calculations.

Quiz Practice Problems

Key ideas: Scientists make observations. Quantitative observations involve measurements. Every measurement has uncertainty associated with it. The uncertainty in a measurement is reflected in significant figures.
Uncertainty is propagated through calculations (uncertainty in measurement (data) --> uncertainty in calculated result).

Skills: Determine significant figures in a number.
Determine uncertainty in a measurement and relate uncertainty to signficant figures.
Do a conversion using dimensional analysis.
Determine the uncertainty in a calculated result by applying significant figures in calculations rules.

1. Determine the number of significant figures and the uncertainty in the measurement.
Example: m.p. of gold = 1067^{o}C. 4 sig figs. Uncertainty = ±1^{o}C
a. f.p. of water = 273 K
b. f.p. of water = 32^{o}F
c. 1 K = 1.8^{o}F. Compare the uncertainties in part a and part b. Which number has the smaller uncertainty?
d. size of cell = 10 micrometers. If the uncertainty is ±1 micron, how many sig figs should you use?
e. circumference of earth = 24,000 miles. Based on the number of sig figs, this uncertainty does not make sense. How many sig figs should you report?

"When Scientific Predictions Are So Good They're Bad", By William K. Stevens, NY Times, September 28, 1998. Let's say you work for the National Weather Service (NWS). It has been raining for days and the river that runs through town is rising. The NWS forecast (prediction) was the river would crest at 49 feet. The town would flood if the river rose above 52 feet. It turned out the river crested at 54 feet.
How would you report the height at which the Red River of the North would crest so people would account for the uncertainty in the prediction? In other words, how many significant figures would you use in the predicted height at which the river would crest? Give reasons.

Answers:
a. 273 K has 3 significant figures. Uncertainty = ±1 K. Uncertain digit is the one's place.
b. 32^{o}F has 2 significant figures. Uncertainty = ±1^{o}F. Uncertain digit is the one's place.
c. 273 K has the smaller uncertainty.
d. 2 significant figures. Report size of cell as 10. microns or 1.0x10^{1} microns.
e. 24,000 has 2 significant figures. Uncertainty = ±1,000 miles.
Use 4 significant figures so 2.400x10^{4} miles.
NWS forecast: use 1 significant figure (10's place) = 50 feet ±10 feet but most people may not know what this means.
Use 2 significant figures (1's place) = 49 feet ±5 feet. Use larger uncertainty in one's place.

Significant figures in calculations
2. a. The mass of an empty flask is 116.4 g. The mass of the flask with 25 ml of liquid is 141 g. Calculate the mass of liquid. (Should you look at sig figs or decimal places?)
b. The mass of water is 49.05 g. The density of water is 0.9965 g/ml. How many sig figs are in each number? What equation should you use? Calculate the volume of water. (Should you look at sig figs or decimal places?)
Answers:
a. mass of liquid = mass of liquid + flask – mass of flask.
Subtract so use decimal places.
mass of liquid + flask = 141 g has 0 decmial places.
mass of flask.= 116.4 g has 1 decmial place.
mass of liquid = 25.4 g has 1 decimal place. Round to 0 decimal places
so mass of liquid = 25 g
b. mass of water = 49.05 g has 4 significant figures.
density of water = 0.9965 g/ml has 4 significant figures.
Density = mass/volume
Rearrange equation so Volume = mass/density
Volume of water = mass of water /density of water
= 49.05 g/0.9965 g/ml
= 49.222 ml has 5 significant figures. Round to 4 significant figures
so Volume of water= 49.22 ml

3. You measure mass of water to be 49.05 g. The molar mass of water is 18 g/mole. Calculate the moles of water. Use molar mass = mass/moles.

Answer: you know (given) mass and molar mass. You want to find moles.
Rearrange molar mass = mass/molar mass and solve for moles.
Moles = mass/molar mass
= 49.05 g water/(18 g/mole)
= 2.725 moles ==> round to 2 significant figures (one factor has 4 s.f. and the other factor has 2 s.f.)
==> 2.7 moles.

4. You want to calculate how much heat is needed to raise the temperature of 1 cup (240 g) of water from 25°C to 100°C. Use heat = q = m s ΔT, where q = heat, m = mass in g, s = specific heat of water = 4.18 J/g°C, and $\Delta T = T_{final} - T_{initial}$.
Answer: q = m s ΔT = (240 g)(4.18 J/g°C)(100°C - 25°C)
2 s.f. 3 s.f. 2 s.f.
= 75240 J ==> round to 2 significant figures
= 75000 J

5. You measure the pressure in a balloon to be 0.98 atm, balloon volume is 1.3 liters, and the temperature is 302 K. Calculate the moles of air in a balloon using the ideal gas law: PV = nRT, where P = pressure in atm, V = volume in L, n = moles, R = gas constant = 0.082 L atm/mole K, and T = temperature in K.
Answer: solve for n from the equation, PV = nRT
n = PV/RT = (0.98 atm)(1.3 L)/(0.082 L atm/mole K)(302 K) = 0.0514 moles ==> round to 2 significant figures
n = 0.051 moles

6. a. You measure the mass of an empty beaker to be 40.01 g. The mass of the beaker and 10.00 ml of of a colorless liquid is 49.05 g. The density is ____ g/ml. (Use three sig figs in your density calculation.)
b. Which volume measuring device was used, 10 ml graduated cylinder, 50 ml graduated cylinder, or 150 ml beaker? (10 ml graduated cylinder)
c. Is the colorless liquid water or ethanol? Give reasons.
Answers:
a. mass of liquid = mass of the beaker and 10.00 ml of of a colorless liquid - mass of an empty beaker
= 49.05 g - 40.01 g
= 9.04 g (subtract so use decimal places to determine significant figures)
Density of liquid = mass of liquid/volume of liquid
= 9.04 g/10.00 ml
= 0.904 g/ml ==> round to 3 significant figures
= 0.904 g/ml

Quiz Practice Problems for Dimensional Analysis
Dimensional analysis (Factor-label method): a x (b/a) = b. What is the conversion factor? Make sure units cancel out to give you the units you want.
Some conversion factors: 1 kg = 2.2 lb
molar mass of an element or compound is the mass in g of 1 mole of the element or compound = mass/mole
density is the mass of 1 ml of a pure substance = mass/volume
Concentration is the moles of solute in 1 liter of solution = moles/volume
Chemical formula subscripts represent mole ratios of elements
Coefficients in balanced chemical equation represent mole ratios of reactants/products

1 step conversions:
1. Do the following conversions. Use sig figs.
a. A sack of rice has a mass of 22.7 kg. Calculate the mass in lb. What is the conversion factor?
b. You have 28 g of gold. Calculate the moles of gold. What is the conversion factor? (molar mass)
c. You have 1 tsp = 6 g of sugar ($C_{12}H_{22}O_{11}$). How many moles of sugar are in 1 tsp? What is the conversion factor?
d. How many moles of carbon are in 1 tsp of sugar? What is the conversion factor?
e. You have 1 ounce (30 ml) of alcohol (ethanol). Calculate the mass. What is the conversion factor? (density)
f. You need 0.5 moles of NaCl in a 0.1 M NaCl solution. Calculate the volume of the 0.1 M NaCl solution that is needed. What is the conversion factor? (concentration)
Molar concentration (symbol = M) is the moles of solute in 1 liter of solution.
Example: 1 M means 1 Molar concentration solution = 1 mole of solute in 1 liter of solution.
So 1 M sugar solution = 1 mole of sugar in 1 liter of solution.
g. You have 0.75 moles of salt (NaCl). Calculate moles of sodium in the 0.75 moles of salt. What is the conversion factor?
k. $CH_4 + 2\ O_2 \rightarrow CO_2 + H_2O$
0.25 moles of CH_4 burns. Calculate the moles of CO_2 produced. (balanced chem equation)
l. $2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$

0.25 moles of C_8H_{18} burns. Calculate the moles of CO_2 produced. (balanced chem equation)
m. Which fuel, CH_4 or C_8H_{18}, produces more CO_2 per mole of fuel burned?
o. When 1 mole of CH_4 burns, 802 kJ of energy is released as heat. Calculate the amount of energy released when 1 g of CH_4 burns. What is the conversion factor?
p. The energy of electromagnetic radiation is: $E = h\nu = hc/\lambda$ where h = Planck's constant = 6.63E-34 J sec, ν = frequency = Hz (sec^{-1}), c = speed of light = 3.00E8 m/sec, λ = wavelength in m. The red light in a supermarket scanner is from a He-Ne laser which has a wavelength of 656 nm. Calculate the frequency in Hz.
Answers: These are conversions that you will do in Chem 1A.
a. 22.7 kg has 3 significant figures
22.7 kg (2.2 lb/1 kg) = 49.94 lb ==> round to 3 significant figures ==> 49.9 lb
b. 28 g has 2 significant figures
28 g gold (1 mole gold/197 g gold) = 0.142 moles gold ==> round to 2 significant figures ==> 0.14 lb
Conversion factor is molar mass of gold. See Periodic Table.

Mass in g to moles is a common conversion in chemistry.
c. 1 tsp sugar has 1 significant figure.
1 tsp sugar (6 g sugar/1 tsp)(1 mole sugar/342 g sugar) = 0.01754 moles sugar ==> round to 1 significant figure ==> 0.02 moles sugar.
Conversion factor is molar mass of sugar. See Periodic Table for molar masses of C, H, and O. Multiply molar mass of element by subscript.

Moles of one substance to moles of another substance is a common conversion in chemistry.
d. Use answer from (c). 0.01754 moles sugar (12 moles carbon/1 mole sugar) = 0.00146 moles C.
1 tsp sugar has 1 significant figure ==> round to 1 significant figure ==> 0.001 moles C.
Note: do not round an intermediate result (0.01754 moles sugar). Round the final result.
Conversion factor is mole ratio of carbon to sugar from chemical formula, $C_{12}H_{22}O_{11}$.

Volume in ml to g is a common conversion in chemistry. Density is the conversion factor.
e. 1 ounce ethanol (30 ml ethanol/1 ounce ethanol) (0.79 g ethanol/ 1 ml ethanol) = 23.7 g ethanol.
1 ounce ethanol has 1 significant figure ==> round to 1 significant figure ==> 20 g ethanol.
Conversion factor is density of ethanol.
f. Molarity = moles/Volume of solution
Rearrange and solve for Volume of solution = moles/Molarity
= 0.5 moles/0.1 M
= 5 liters of 0.1 M NaCl
g. The conversion factor is 1 mole Na/1 mole NaCl. Use the subscripts in the chemical formula to determine the ratio of Na to NaCl.
0.75 moles NaCl (1 mole Na/1 mole NaCl) = 0.75 moles Na
k. Conversion factor is 1 mole CH_4 /1 mole CO_2. Use the coefficients in the balanced chemical equation to determine the ratio of reactants to products.
0.25 moles of CH_4 (1 mole CO_2 /1 mole CH_4) = 0.25 moles CO_2.
l. Conversion factor is 2 moles C_8H_{18} /25 moles CO_2. Use the coefficients in the balanced chemical equation to determine the ratio of reactants to products.
0.25 moles of C_8H_{18} (25 moles CO_2/2 moles C_8H_{18}) = 3.125 moles CO_2.
round to 2 significant figures ==> 3.1 moles C.
m. 0.25 moles of CH_4 produces 0.25 moles CO_2 or 1 mole of CH_4 produces 1 mole CO_2.
0.25 moles of C_8H_{18} produces 3.1 moles CO_2 or 1 mole of C_8H_{18} produces 12.5 mole CO_2.
So C_8H_{18} produces more CO_2 per mole of fuel burned.
o. Mass in g to moles or moles to g is a common conversion in chemistry.
Molar mass of CH_4 is the conversion factor.
Energy released (exothermic) is defined as negative energy. Energy absorbed (endothermic) is defined as positive energy.
-802 kJ/mole CH_4 (1 mole CH_4 /16 g CH_4) = -50.125 kJ/g CH_4.
round to 3 significant figures ==> -50.1 kJ/g CH_4.
p. $E = h\nu = hc/\lambda$
Or $h\nu = c/\lambda$
Or $\nu = c/\lambda$ = 3.00E8 m/sec (656E-9 m) = 4.57E14 sec^{-1} = 4.57E14 Hz.
656 nm (1E-9 m/1 nm) = 656E-9 m

2. 2 step conversions:
a. You have 6 g of NaCl. Calculate the moles of sodium in this mass of salt. What are the conversion factors? (molar mass and mole Na to mole NaCl)

b. (3 step conversion) You have 6 g of NaCl. Calculate the mass of sodium in this mass of salt. What are the conversion factors?
c. You have 6 g of sugar ($C_{12}H_{22}O_{11}$). Calculate the mass of carbon in this mass of salt. What are the conversion factors?
d. One can (12 oz. = 360 ml) of soda contains 39 g of sugar (high fructose corn syrup, $C_6H_{12}O_6$).
(i) You want to drink only 1 Calorie (there are 4 Calories in 1 g of sugar). How many ml of soda should you drink?
(ii) How many Calories are in one can of soda?
(iii) What is the Molar concentration of sugar in soda?
e. $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$
0.25 g of CH_4 burns. Calculate the moles of CO_2 produced. (balanced chem equation)
(3 step conversion) 0.25 g of CH_4 burns. Calculate the mass of CO_2 produced.
Answers: These are conversions that you will do in Chem 1A.
a. Convert g NaCl --> moles NaCl --> moles Na
6 g of NaCl (1 mole NaCl/58.5 g NaCl)(1 mole Na/1 mole NaCl) = 0.103 moles Na
round to 1 significant figure ==> 0.1 moles Na
b. Convert g NaCl --> moles NaCl --> moles Na --> g Na
6 g of NaCl (1 mole NaCl/58.5 g NaCl)(1 mole Na/1 mole NaCl)(23 g Na/1 mole Na) = 2.359 g Na
round to 1 significant figure ==> 2 g Na
c. Convert g sugar --> moles sugar --> moles C --> g C
6 g of $C_{12}H_{22}O_{11}$ (1 mole $C_{12}H_{22}O_{11}$/342 g $C_{12}H_{22}O_{11}$)(12 mole C/1 mole $C_{12}H_{22}O_{11}$)(12 g C/1 mole C) = 2.526 g C
round to 1 significant figure ==> 3 g C
Note the mass of C must be less than the mass of sugar.
d. (i) Convert Calories --> g sugar --> ml soda
1 Calorie (1 g sugar/4 Calories)(360 ml of soda/39 g sugar) = 2.31 ml soda
round to 1 significant figure ==> 2 ml soda
(ii) Convert can soda --> g sugar --> Calories
1 can of soda (39 g sugar/1 can of soda) (4 Calorie / 1 g sugar) = 156 Calories
Use mass of sugar to round to 2 significant figures ==> 160 Calories
(iii) Molarity of sugar = moles of sugar/volume of solution
= 39 g sugar (1 mole $C_6H_{12}O_6$/180 g $C_6H_{12}O_6$)(1/360 ml)(1000 ml/1 l) = 0.602 M
round to 2 significant figures ==> 0.60 M
e. 0.25 g CH_4 (1 mole CH_4 /16 g CH_4) (1 mole CO_2 /1 mole CH_4) (44 g CO_2 /1 mole CO_2) = 0.6875 g CO_2.
round to 2 significant figures ==> 0.69 g CO_2.

3. Algebra – rearrange an equation:
a. $q = m\ s\ \Delta T$ where q = heat in J, m = mass in g, s = specific heat in J/g°C, and ΔT = difference in temperature = $T_f - T_i$.
Water absorbs 26,100 J of energy to heat up some water 25°C. The specific heat of water is 4.18 J/g°C. Calculate the mass of water that was heated. (Answer: between 240-260 g)
b. Ideal gas law: PV = nRT where P = pressure in atm, V = volume in liters, n = moles, R = gas constant = 0.082 l atm/mole K, and T = temperature in K
You have a balloon filled with air at P = 1.00 atm, V = 20.0 liters, T = 300K. Calculate n = moles of air in the balloon.
Answers: These are conversions that you will do in Chem 1A.
a. q = 26100 J, s = 4.18 J/g°C, ΔT = 25°C
rearrange $q = m\ s\ \Delta T$ to solve for m.
$m = q/(s\ \Delta T)$
$= 26{,}100\ J/[(4.18\ J/g^oC)(25^oC)]$
= 249.76 g
round to 2 significant figures ==> 250 g water.
b. P = 1.00 atm, V = 20.0 liters, T = 300K, R = gas constant = 0.082 l atm/mole K.
PV = nRT
Rearrange PV = nRT to solve for n.
n = PV/RT
= (1.00 atm)(20.0 liters)/(0.082 l atm/mole K)(300K)
= 0.813 moles air
round to 1 significant figure based on 1 sig fig in 300 K ==> 0.8 moles air.