1. Define "precision" and "accuracy" in scientific analysis, and explain the difference between the two terms. What statistical quantities are used to measure precision and accuracy?

Precision: reproducibility of the data - measured by standard deviation

Accuracy: agreement with accepted value - measured by % error

2. For solution concentrations, define molarity (M), molality (m), and weight percent. Explain how you would make a 50% NaOH solution.

\[ M = \frac{\text{moles solute}}{\text{L solution}} \]

\[ m = \frac{\text{moles solute}}{\text{kg solvent}} \]

\[ \text{wt} \% = \frac{\text{mass solute}}{\text{mass solution}} = \frac{\text{mass solute}}{\text{mass solute} + \text{mass solvent}} \]

Weigh out equal masses of NaCl and water and combine.

3. The density of sea water is 1.035 g/ml. The concentration of MgCl₂ in sea water is 0.054 M. How many grams of MgCl₂ are in 1.00 kg of sea water?

\[ M_{\text{MgCl₂}} = M \times \text{Mol.} \times \text{MW} = M \times \text{MW} \times \frac{\text{mass solution}}{\rho} \]

\[ \text{MW} = 95.21 \]

\[ = 0.054 \text{ mol} \times 95.21 \text{ g/mol} \times \frac{1.00 \text{ kg}}{1.035 \text{ g/cm}^3} = 49.7 \text{ g} \]

4. You dissolve 145 mg of AlCl₃ in 235 mL of water. For this solution, what is the concentration of chloride ions in ppm?

\[ \text{ppmA} = \frac{M_{\text{Cl}} \times 10^6}{M_{\text{solution}}} = \frac{M_{\text{Al}} \times \% \text{Cl}}{M_{\text{solution}}} \times 10^6 \]

\[ \% \text{Cl} = \frac{3 \cdot \text{AW}_{\text{Cl}}}{\text{AW}_{\text{Al}} + 3 \cdot \text{AW}_{\text{Cl}}} \]

\[ \text{assume solution weighs 235 g} \]

\[ \frac{145 \text{ mg}}{235 \times 10^5 \text{ mg}} = \frac{0.7976}{145} = 49.2 \text{ ppm Cl} \]
5. \(a=8.5\pm0.2, \ b=0.123\pm0.006, \ c=422\pm2\). Which quantity has the greatest relative error, and why? Compute the value of \(a + bc\) with the correct number of significant digits. **Find the propagated error of this value.**

\[
\begin{array}{ccc}
a & 8.5 & 0.2 & 0.024 \\
b & 0.123 & 0.006 & 0.049 \text{ error in } b \text{ dominates} \\
c & 422 & 2 & 0.005 \\
bc & 51.906 & 2.5 \text{ error in } bc \text{ dominates} \\
\end{array}
\]

\[a + bc = 60.406 \pm 2.6 \]

6. Find the mean, standard deviation, standard deviation in the mean, and 95% confidence limits for the following five data: 21.19, 21.22, 21.25, 21.27, 21.34.

\[
\overline{x} = 21.25 \\
\bar{S} = 0.057 \\
t = 2.774 \\
\frac{t_S}{\bar{S}} = 0.071
\]

7. Assume that you have a set of 15 data—each datum in problem 6 appears three times in the set. Repeat the calculation of the statistics for this larger data set, and indicate which values have changed significantly.

\[
\overline{x'} = 21.25 \text{ same as above} \\
S' = \sqrt{\frac{3 \sum (x' - \overline{x'})^2}{3(15-2)}} = 0.053 \text{ slightly smaller} \\
t' = 2.145 \text{ slightly smaller}
\]

\[
\frac{t_{S'}}{\bar{S'}} = 0.029 \\
21.25 \pm 0.03 \text{ } \sqrt{15} \text{ has biggest impact}
\]

8. For your results in both problem 6 and problem 7: Is your mean significantly different from the accepted value of 21.19?

\[
21.25 \pm 0.07 \text{ includes } 21.19 \text{ not sig diff} \\
21.25 \pm 0.03 \text{ in range } \text{ not sig diff}
\]
9. You have an unknown solid mixture made of sodium chloride and barium chloride. You dissolve 3.000 g of the unknown in 100.0 mls of solution. You treat 50.00 mls of this solution with Na₂SO₄ to precipitate the barium. **Write a balanced reaction for this step.** You obtain 534.3 mg of dry BaSO₄. What is the percentage of barium chloride in the original mixture?

\[
\text{BaCl}_2 + \text{Na}_2\text{SO}_4 \rightarrow 2 \text{NaCl} + \text{BaSO}_4
\]

\[
\text{Ba}^{2+} + \text{SO}_{4}^{2-} \rightarrow \text{BaSO}_4
\]

\[
\% \text{BaCl}_2 = \frac{m_{\text{BaCl}_2}}{m_{\text{sample}}} = \frac{M_{\text{BaSO}_4}}{M_{\text{BaCl}_2}} \times \frac{M_{\text{BaCl}_2}}{m_{\text{sample}}} = \frac{M_{\text{BaSO}_4}}{M_{\text{sample}}} \times \frac{MW_{\text{BaCl}_2}}{MW_{\text{BaSO}_4}}
\]

\[
\frac{1}{2} \text{ of weighed sample is treated}
\]

\[
\frac{534.3 \text{ mg BaSO}_4}{1500 \text{ mg sample}} \times \frac{208.27}{233.14} = 31.779\%
\]
10. You have a solid unknown containing calcium carbonate, which is insoluble. Your analytical strategy is to dissolve the solid with a known excess of HCl, which will destroy the carbonate ion (lots of CO₂ bubbles!) and create a solution of CaCl₂ and leftover acid. Write a balanced reaction for this step! You will titrate the leftover HCl with NaOH to figure out how much CaCO₃ was originally present.

You dissolve 1.500 g of the solid using 100.00 ml of 0.1000 M HCl. You titrate this solution with 0.1100 M NaOH and get a nice pale pink end point at 42.56 ml. What is the percentage of CaCO₃ in the solid sample?

\[
\frac{10 \text{ mmol HCl}}{1 \text{ mol HCl}} = \frac{2 \text{ mmol HCl}_\text{leftover}}{1 \text{ mol HCl}_\text{leftover}} = \frac{2 \text{ mmol NaOH}}{1 \text{ mol NaOH}}
\]

\[
\text{mmol HCl}_\text{leftover} = \text{mmol HCl} - \text{mmol HCl}_\text{titration}
\]

\[
\text{mmol HCl}_\text{titration} = \frac{\text{ml NaOH} \times \text{M NaOH}}{1 \text{ L NaOH}}
\]

\[
\text{mmol HCl}_\text{leftover} = \frac{2 \text{ mmol HCl}}{1 \text{ mol HCl}} \times \text{mmol HCl}_\text{titration}
\]

\[
\text{mmol HCl}_\text{leftover} = \frac{1}{2} \text{ mmol CaCO}_3
\]

\[
\text{mmol CaCO}_3 = \frac{\text{mg CaCO}_3}{\text{mg sample}} = \frac{\text{mmol HCl}_\text{leftover}}{2 \text{ mg sample}} = \frac{(\text{mmol NaOH} - \text{mmol HCl}_\text{titration}) \times \text{M NaOH}}{2 \text{ mg sample}}
\]

\[
\frac{10.00 \text{ ml} - (42.56 \text{ ml} \times 0.1100)}{1500 \text{ mg sample}} = 17.74 \%
\]