



INTRODUCTION

General Instructions:

The completion of this Lab does NOT require a formal Lab report or write up. Instead you will present your data by completing a Lab Template. This template is available as a separate document. **Only the completed LAB6: HYDROCHEMISTRY RESULTS needs to be turned in for credit!!!**

Reading Assignments:

In preparation for this Lab and the other pumping lab, READ the following in your FREE Open Access Textbook(s):

- Kresic, 2024, Hydrogeology 101: Lecture 11; 15.1.1
 - Freeze & Cherry, 1979, Groundwater: Chapter 3, Chapter 7
- (Optional) and if you have it, READ the following in your *optional* Textbook:
- Hölting & Coldewey, 2019, Hydrogeology: Section 11; 12; 14

GENERAL INSTRUCTIONS ON COMPLETING THE LAB and GRADING:

For ALL assignments use a citation's database:

ZOTERO citations database

ZOTERO is a citations database that incorporates itself into Word and your Browser.

Free open source software available at <https://www.zotero.org/>

Note: You may use a different citations database, if desired. But you MUST use a citations database!

NOTE: After downloading and installing ZOTERO, take an hour or two to become familiar with the operation of the software. One of your first tasks will be to set the citation style to the United States Geologic Survey (USGS) format in ZOTERO. The USGS citation system will be required for this course and your final product.

Loading the USGS citation format into ZOTERO: Once Zotero Standalone is installed, click on "Preferences" under the Edit tab. Once there click on "Cite" and go to the "Styles" tab. Click on the "Get additional styles..." below the Styles Manager Box. When the Zotero Styles Repository Window opens, click on the "geology" button within the "Fields" section. A list of geology journals should now appear. Scroll down to the U.S. Geological Survey and click on it. The U.S.G.S style will now be part of your Zotero system and you can set your citations to be formatted accordingly in Zotero.

General Writing Instruction Summary:

- Use professional language, which means AVOID first person expressions such as "I", "we", "our". Use normal prose, active voice and third party language. Do NOT use informal wording, contractions, jargon, slang terms, or superlatives. Exclude similes/metaphors (and humor!)
- Use present tense to report well accepted facts, e.g. 'Pyrite is a sulfide mineral'. Use past tense to describe specific results, e.g. 'When acid was applied, the specimen effervesced'
- Be quantitative wherever relevant (stats, numbers etc.).

Subscript & Superscript

Use appropriate subscript and superscript, especially when it comes to chemical formulas and mathematical units..

Acceptable examples: 2.9 g/cm^3 , H_2O , PO_4^{3-} , $a_g=9.8\text{m/s}^2$

Unacceptable examples: 2.9 g/cm^3 , H_2O , PO_4^{3-} , $a_g=9.8\text{m/s}^2$

- Use precise concrete language, no ambiguity e.g. 'correlated' \neq 'related'. Use simple language – no unnecessary "frills" (distractions). Pay attention to sentence structure and grammar



COMPILING TABLES, FIGURES and EQUATIONS

GRAPHICS are the heart of any report. Nothing is more true than in science that a picture is worth a thousand words. Always compile graphics first and then write your text focusing on your graphic. In order to create good graphics and photographs, follow the instructions below.

Cameras and Photos:

Cell phones with a 7.2MP camera are usually ok. When taking pictures, lighting and background is key. This means dark objects should be photographed with light or white backgrounds (sheet of paper) and visa versa for light objects. Having adequate lighting will also help to get sharp, crisp, in focus pictures. Blurry and out of focus pictures are not acceptable.

Graphics:

You should be able to modify, enhance, annotate or overlay graphics. Minimum resolution is 300dpi. Make sure graphics are crisp, clear and any label is easily readable. All graphics should have a caption stating the author and/or citation. Preferably use lossless graphic formats, such as .tif or .bmp. Unfortunately .jpg is NOT lossless and will degrade a little every time you open and save it again in order to manipulate picture contents.

Graphics Editor Software: You will need a graphics editor and learn how to use it. Windows comes with its default Windows Paint editor. It is found in the Windows Accessories Folder. For a more advanced option with many more professional features you may try GIMP: <https://www.gimp.org/> This is a FREE, open source image editor working across all computing platforms (Windows, Apple, Linux, etc.). The software comes with ample documentation and examples on how to manipulate any picture or graphic.

Screen Capture Software: A screen capture or snipping software is advantageous in order to only grab the part of a graphic from the screen that is important or necessary. Windows 10 comes with a default snipping tools, such as “Snip & Sketch” found in its own folder or “Snipping Tool” found in the Windows Accessories Folder. Note: When snapping a picture, make sure it is large enough on the screen to capture enough pixels to have adequate resolution for the final product.

NOTE: Compiling acceptable and good looking graphics and photographs is very involved and can not be rushed. These are often the heart of any report and should be compiled BEFORE writing. Last minute thrown together graphics will without doubt lower your grade.



COMPOSITION, LAYOUT, WRITING & GRAMMAR SUMMARY

Language

The following list is an example of common faults in language usage and attribution.

Errors / Mistakes / Faults	Examples with margin <i>Fault Counts & Codes</i>
Spelling: incl. capitalization errors & spacing	The mineral <u>florite</u> has a <u>mohs</u> hardness of four. Nicolas Steno_ was trained in the classical texts on science.
Grammar: incl. punctuation, superfluous words, transpositions	Isometric crystals are also isotropic Here light propagates at the same speed. Rocks are composed of many many <u>minerals mixed.</u>
Style: incl. paragraph, repetitive expressions / words, erroneous expression / words, sub- or superscription, unprofessional style, word insertion	<i>Para.</i> ... in the geologic sciences. ¶ Near the end of the 19 th a new theory ... <i>rep</i> ... is a <u>light colored</u> mineral. These <u>light colored</u> minerals are often <u>light</u> ... Stalactites hang from the <u>sealing?</u> of a limestone cave. <i>sup</i> The density of quartz is 2.65 g/cm ³ . I was investigating the outcrop with <u>my group</u> . Sodium sulfate forms a chalky, <u>incoherent</u> precipitate. <i>amorphous?</i> ^
Sentence: incl. grammar, run-on, strings of nouns	The density of gold is greater <u>then?</u> the density of silver. Pyrite has a symmetrical crystal <u>structure</u> , it is cubic. <u>Skarn mineral zonation?</u> is apparent in the sample.

Content

Errors in content are spelled out. Severe infractions may count for multiple errors.

Errors / Mistakes / Faults	Examples with margin <i>Fault Counter & Codes</i>
Unclear / erroneous statements	<i>unclear, units?</i> Mohs hardness of the mineral in question is 16.5.
False / nonsense	<i>Nonsense</i> Glaciation cause severe metamorphism of the region

TABLES, FIGURES & EQUATIONS SUMMARY

Tables	Each table must be sufficiently complete that it could stand on its own, separate from text. <p style="background-color: yellow;">Only HORIZONTAL lines are allowed in tables. Do NOT use any VERTICAL lines.</p> <p>DO consecutively number and caption tables and refer to them accordingly within your text. Captions go ABOVE the table. DO provide a short description of your table within the caption. DO place your tables appropriately, closest to their mention in the text. DO make sure tables are legible and reproduce well. Print can be smaller than text, with an 8pt size minimum. DO appropriately label columns. Do NOT forget units for numeric values.</p> <p>AVOID splitting tables across pages.</p>
---------------	--

**Figures**

Each figure must be sufficiently complete that it could stand on its own, separate from text.

DO number and caption figures consecutively and refer to them accordingly within your text. Captions go BELOW the figure.

DO provide a short description of your figure within the caption.

DO place your figures appropriately, closest to their mention in the text.

DO use appropriate citations for figures that are NOT your own. If you use a figure that has been modified by you, the phrase “modified after....” is most appropriate. Photos should show the name of the photographer.

DO make sure figures are legible and reproduce well. Print can be smaller than text, with an 8pt size minimum. Use a minimum resolution of 300dpi. This is a common publication standard.

AVOID cluttering of figures with too much detail. Simplify if necessary.

AVOID moire patterns in photos, a nuisance in copied or scanned pictures. Most scanners come with a moire pattern removal tool.

GRAPHS

Understand graphs: Bar graphs and/or line graphs are used when plotting nominal vs. ratio or interval data. Scatter plot graphs are used when plotting numeric vs. numeric data.

DO make sure that the graph axis are appropriately labeled and scaled. Axis should have titles as well as scalar units.

DO use electronic means to generated graphs. Hand drawn graphs are no longer acceptable.

Equations & Computations

- Equations should contain explanation of symbols used.
- A reader should be able to follow where your values or numbers come from. Indicate accordingly.
- WRITE DOWN UNITS!!!!
- Show equations used before indicating any computation

Acceptable Example: $F = m \times a = 0.034\text{kg} \times 9.8\text{m/s}^2 = 0.33\text{kgm/s}^2$

where m is mass of the object in kg as determined with a triple beam balance and a is the gravitational acceleration. F indicates force expressed in kgm/s^2 or N (Newtons).

Unacceptable example: The answer is 0.33. This is obtained by multiplying gravity by 0.034.

Introduction: Groundwater Quality (Hydrochemistry)**General Instructions:**

Drinking water quality is an important aspect of Hydrogeology. Not only for drinking water safety, but also for water classification and for the deciphering of the evolution of water. The ionic background concentration can tell which subsurface geologies or minerals might have been in contact with the water and will influence water quality.

During this LAB you will learn sampling and measurement procedures, water analysis and interpretation and classification of TWO water samples. One sample will be your own household tap water, the other a store-bought mineral water of your choice.

What you will need:

1. Tap water sample
2. Store-bought mineral water sample. **Note: Make sure it is indeed REAL mineral water and not just “purified Water” with minerals added. Also make sure that there are NO flavors added! Examples of REAL mineral water: San Pellegrino, Perrier, Gerolsteiner, Fiji Water, Apollinaris, etc.**
3. Access to our ICP-MS and Anion Chromatograph instrumentation (contact our Lab Coordinator for access)
4. pH Meter and electric conductivity meter
5. Bicarbonate Titration Set-Up
6. HACH or LaMOTTE photospectrometric sulfate analysis



The Measurements and Computations:

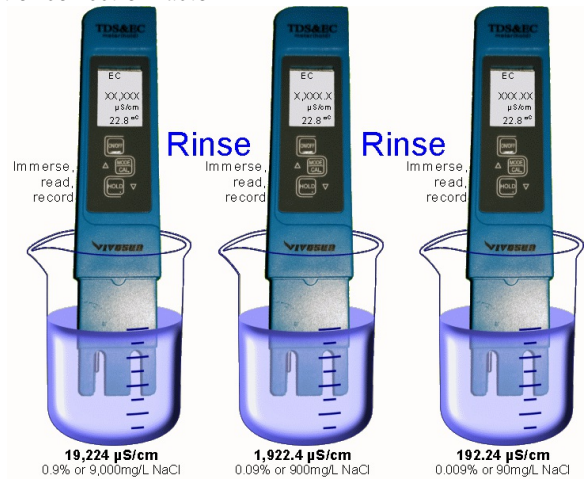
I. Electric Conductivity and TDS Measurement

A. Calibrate your TDS / Mhos Meter and compute error drift or correction factor

1. A calibration solution series can be made from Saline Irrigation solutions sold at your local pharmacy or drug store. This solution is set to exactly 0.9% NaCl concentration, which can be diluted with DI water to create a measurement series.
2. Most likely these TDS meters cannot be calibrated. Hence you will calculate the error for each measurement, come up with a correction factor that would mitigate this error, and then take the average correction factor to be used for ALL your analytical work with the TDS meter.

B. Take your TDS and Mhos readings of your samples. Apply the correction factor and record the results.

C. Also compute the TDS manually from your Mhos readings.



II. pH Measurements of your Samples

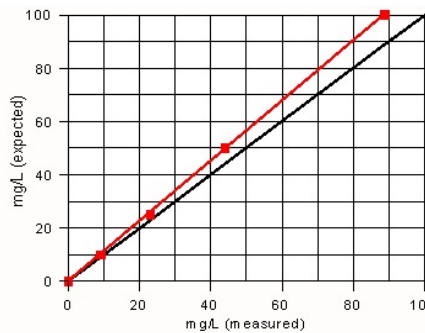
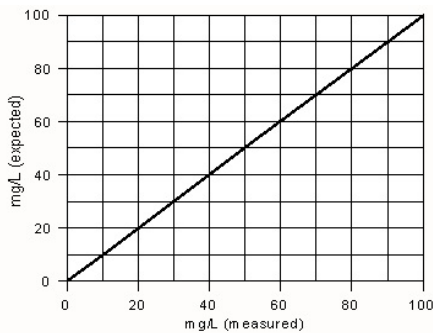
A. We will use an inexpensive consumer pH meter, which is generally good enough for our measurement purposes.

1. Calibrate the pH meter first by making the calibration solutions and following the instructions in the instrument manual.
2. Take and record your pH measurements.



III. Measuring the Sulfate Concentration with the HACH DR900 VIS Spectrometer

- A. Contact our Lab Coordinator to make sure we have the instrument and chemicals on hand.
- B. Sulfate ions in the sample react with barium chloride in aqueous solution and form a precipitate of barium sulfate. The resulting turbidity is measured photometrically. The upper detection limit is about 70mg/L SO₄ with this method.
- C. Download the [Instrument Brochure from HACH](#)
- D. Download the [Method / Procedure 8051 Brochure from HACH](#)
- E. Do a calibration series to record, evaluate and correct possible measurement errors and to establish a correction factor. See graphical solution example:



Instrument Drift Correction:
 $y \text{ (expected)} = mx \text{ (measured)} + b$
 $y \text{ (expected)} = 80/70x \text{ (measured)} + 0$
 $y \text{ (expected)} = 1.143x \text{ (measured)}$

F. Measure your samples, correct the answers (if applicable) and record your corrected results.




G. Clean-up instructions:

1. The contents of cuvettes with solid Sulfate Reagent are considered Toxic Waste. Please dump contents in appropriate disposal container, NOT down the sink.
2. Clean cuvettes meticulously with warm, soapy water and most importantly WITH micro-brush . Take care NOT to scratch the cuvettes in any way, shape or form.
3. Clean all used labware in the same manner.
4. Rinse cuvettes / labware several times with tap water. Final 2 to 3 rinses should be with DI water.
5. Set cuvettes on soft paper towel to dry.
6. Power instruments down. Wipe up any spills on instruments and/or desks/counters.
7. Put equipment back into original storage boxes and/or place on cart or counter.
8. Put Sulfate Standards, Reagents and other Lab Equipment back.

IV. Bicarbonate Titration Measurements

A. Bicarbonate Measurement Standard is by Titration. Make sure chemicals as listed are at hand.

<p>MATERIALS: Titration burette, 200mL beaker / Erlenmeyer flask, Cooper-Indicator, 50mL 0.1n HCl, Vessel with CaCO₃ chips for waste disposal</p>	
<p>PROCEDURE: Place 100.00mL water sample into flask. Add 5 drops Cooper indicator. Your water sample should turn blue. Fill titration burette with 0.1n HCl. Carefully drop HCl from burette into flask. Shake flask continuously or use stirrer. When the exact point of color change from blue to onion-skin color is achieved, stop adding HCl. The exact point is achieved when the blue color has disappeared.</p>	
<p>NOTES: <i>Depending on the amount of HCO₃⁻ present, you may go faster at first, but at the end it is one drop at a time. Your point of color change MUST BE EXACT.</i></p>	
<p>RESULTS: Carefully record mL of HCl used. Then use the equation below to calculate HCO₃⁻ in mg/L: <i>Note:</i></p> $\text{---} \frac{\text{mg}}{\text{L}} \text{ HCO}_3 = \left(\frac{\text{---} \text{mL}_{0.1\text{nHCl}} \times 0.1\text{n}_{\text{HCl}} \times 1000 \frac{\text{mmol}}{\text{mol}}}{100.00\text{mL}_{\text{H}_2\text{O}}} - 0.005 \frac{\text{mmol}}{\text{L}} \right) \times 61 \frac{\text{mg}}{\text{mmol}} \text{ HCO}_3$ <p><i>n = m = mol/L; 0.005mmol/L = acid correction factor due to H₂CO₃</i></p>	
<p>CLEAN-UP: Dump flask contents into vessel with CaCO₃ chips. Rinse flask with tap water and discard rinse into CaCO₃ chipped vessel. Use dish soap & bottle brush to clean flask. Rinse thoroughly with tap water, discard rinse into sink. Do a final rinse with DI water, discard rinse into sink. Dry outside with paper towels, put away to dry. Empty left over burette contents into vessel with CaCO₃ chips. Rinse thoroughly with DI water and discard into same vessel. Dry outside with paper towels, put away to dry. Put stands, clamps and other materials away. Wipe down work area with paper towels.</p>	
<p>Making a 0.1nHCl solution from concentrated 37% HCl! 8.33cm³ of 37% HCl in 991.67cm³ DI water. (37% HCl = 12M HCl = 12N HCl; 8.33cm³_{37%HCl} = 0.1N_{HCl} * 1000cm³/12N_{HCl})</p> <p>Making Bicarbonate Titration Indicator after Cooper Dissolve 0.02g methyl red and 0.10gbromocresol green in 100mL 95% alcohol.</p>	



V. ICP-MS and Anion Chromatographic Analysis and Computations

A. Have well labeled, clean, unadulterated water samples ready to give to our Lab Coordinator for ICP-MS and Anion Chromatograph Analysis.

1. If your sample needs to be diluted for analysis, prepare your sample accordingly, note the dilution factor and prepare a BLANK with the dilution water.

Note: There is really very little for you to do during the analysis. You can watch the instrument do it, if you would like.

B. **CREATE A SPREADSHEET** from the analytical results to do the computational analysis

1. **Remove nonsensical results** from the ICP-MS analysis (e.g. N, O, He, Ar, etc.) Some of these are part of the carrier gas or were introduced during dilution.
2. **Subtract the sample BLANK** (if applicable). Resulting values with negative numbers are reported as ZERO.
3. ICP-MS results are going to be in ppb or $\mu\text{g/L}$. **CONVERT to ppm or mg/L!** (Divide by 1,000)
Note: The IC anion data is undiluted and already in mg/L (or ppm). No adjustment necessary here.
4. For each **Cation and Anion list the AMU** (atomic mass unit). For single elemental cations or anions, these values can be copied from a periodic table of elements. For polyatomic ions (e.g. SO_4), these must be calculated.
5. List **all ionic charges** for each cation and anion, for example $\text{Ca} = +2$, $\text{Na} = +1$, $\text{Cl} = -1$, $\text{SO}_4 = -2$, etc.
6. Create another row (or column) in your Excel spreadsheet. Here you will enter all mg/L (or ppm) values as **mmol/L**. Conversion: $\text{mg/L} \div \text{AMU} = \text{mmol/L}$
7. In another row (or column) in your Excel spreadsheet enter all mmol/L values as **meq/L**. Conversion: $\text{mmol/L} \times \text{Ionic charge} = \text{meq/L}$

	Ca	Na	Cl	Mg	S	K
AMU	40.08	22.99	35.45	24.31	32.07	39.10
Charge	2	1	-1	2	-2	1
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
F09GW001-U	435.79	186.36	130	78.17	40	26.94
	mmol/L	mmol/L	mmol/L	mmol/L	mmol/L	mmol/L
F09GW001-U	10.873	8.1061	3.7	3.216	1	0.6890
	meq/L	meq/L	meq/L	meq/L	meq/L	meq/L
	21.746	8.1061	-3.7	6.431	-2	0.6890

C. **CATION-ANION BALANCE** calculation and error computing

1. Calculate the CATION-ANION balance by summing up ALL meq/L of Cations and ALL meq/L of Anions. The Anion sum is most likely a negative number since you used the minus charges when calculating meq/L. In this case add the negative anion sum of meq/L to the positive cation sum of meq/L. If you get a ZERO, then your water sample has completely balanced cations and anions. This is most likely NOT the case and some error will usually be implied.
2. To compute CATION-ANION balance error, set all meq/L numbers to positive numbers by simply reversing the sign. Now add the CATION meq/L SUM and the ANION meq/L SUM together. This is your 100% base.
3. Now divide this CATION-ANION meq/L SUM into the CATION-ANION difference of meq/L of the two and multiply by 100. This is your CATION-ANION Balance Error and tells you how good your chemical analysis of the water is. If the error is large, greater than 5%, something is usually

wrong!

D. **GROUNDWATER CLASSIFICATION** create Piper diagram to classify your water type

1. From **meq/L data** recalculate the following major cations and anions to 100%:
 - a. **Cations:** Ca, Mg, Na+K. Sum of all 3 to equal 100%
 - b. **Anions:** Cl, SO_4 , $\text{HCO}_3 + \text{CO}_3$. Sum of all 3 to equal 100%
2. Plot **Cation %** on the Cation ternary diagram of the Piper diagram





3. Plot **Anion %** on the Anion ternary diagram of the Piper diagram
4. Project your ternary plots into the Piper diamond plot
5. From the results, describe your groundwater classification

Only turn in the [LAB6: HYDROCHEMISTRY](#) page for grading after completion.