# Precipitation Case Study

Group Member 1:

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# Instructions

* Please enter your first and last name as it appears on the eLC roster.
* Your UGA myID is a combination of letters and numbers (example: mine is jmj81738). Do *not* enter your 81x number.
* Your completed worksheet has to be submitted to Gradescope:
  + You can use an app (Adobe Acrobat Reader recommended) fill in the fillable pdf.
  + One group member should upload the filled-out pdf to Gradescope.
  + They then need to go into their submission and add all other group members.
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  + You must make sure the pages are in the correct order and have the same layout as the original worksheet when submitting to Gradescope.
  + Answers must be written in the corresponding answer boxes.

# Precipitation Case Study

Water Remediation

Water contamination has long been known to be a significant global challenge.1 Heavy metals, phosphates, and organic compounds are pollutants known to pose risks to both the environment as well as human health.1-2 Furthermore, as industrialization continues to grow, so does the concern of finding these contaminants in water due to their bioaccumulation in ecosystems and the impact on the human food chain. An estimate released by the United Nations in 2011 estimated that 300-500 million tons of heavy metals and other waste are released into the world’s water supply annually as a direct result of industrial activity.3 Heavy metals can also be released naturally into the environment through forest fires, volcanic eruptions, the release of marine salt, and the wind erosion of soil.1 These metals are also of significant concern because they are not biodegradable and have a tendency to accumulate in living organisms. There are several approaches that have been adopted to help remove contaminants from water, including chemical precipitation.4-7 This process involves turning contaminants into insoluble compounds by the addition of select chemical reagents, which can then be separated from water through processes such as sedimentation or filtration.

1. Read the article “Remediation of heavy metals in drinking water and wastewater treatment systems: Processes and applications” (posted on eLC) and answer the questions below.
2. It is well understood that select heavy metals are essential for human health, yet the presence of these metals in high concentrations in water are also known to be of serious concern. What are some of these concerns? Answer this question in ~3-4 sentences.

**Answer: multiple answers are acceptable here; should be referenced directly from the article**

1. What are some of the advantages and disadvantages to using chemical precipitation in water remediation? Answer this question in ~3-4 sentences.

**Answer: multiple answers are acceptable here; should be referenced directly from the article**

1. Various approaches beyond chemical precipitation are discussed in this article that are used in water remediation. Discuss at least two different techniques that may be used and a brief synopsis of each. Answer this question in at least ~4-5 sentences.

**Answer: multiple answers are acceptable here; should be referenced directly from the article**

1. When considering the precipitation of heavy metals, what are some examples of anions that should be avoided when choosing a chemical? Answer this question with at least 2 examples.

**Answer:** **nitrate, acetate, etc. (i.e. anions that have high solubility in water)**

Hypothetical Experiments

For this section, we will consider different experiments conducted by Parker, a scientist working in a water remediation plant. A large component of their job is exploring different ways chemical precipitation can be leveraged to best remediate water samples.

1. Parker goes to lab and finds a few water samples that have been prepared with exact concentrations of different metals. The samples have been labeled with units of parts per million (ppm) or parts per billion (ppb) which are defined below.

ppm = × 106 or

ppb = × 109 or

**Instructor Note: to simplify this, students can be given the concentration in g/mL directly, so they do not have to perform the density conversion.**

Convert the concentration of the samples given below to molarity (M). Since these samples are very dilute, we can assume the density of each aqueous solution is 1.00 g/mL.

1. 10.0 ppm Cd2+

**Answer: 8.90 × 10−5 M**

1. 2.45 ppm Zn2+

**Answer: 3.75 × 10−5 M**

1. 36 ppb Cu2+

**Answer: 5.66 × 10−7 M**

**Instructor Note: This can be removed if solution stoichiometry has not been covered.**

1. Parker is going through the laboratory space and they come across Al2(SO4)3·14H2O (i.e. alum) which has historically been used in water treatment. They subsequently treat a 259.4 g sample of water that contains phosphate with an excess of alum producing 0.0128 grams of AlPO4. Based on this information, what was the original concentration of phosphate in this water sample (in units of ppm)? The balanced equation is given below.

Al2(SO4)3·14H2O (aq) + 2 PO43− (aq) → 2 AlPO4 (aq) + 3 SO42− (aq) + 14 H2O (l)

**Answer: 19.2 ppm**

1. While they were going through the lab space, Parker also finds a few different flasks with various concentrations of Cr3+. Parker has previously read about the effectiveness of remediating Cr3+ with MgO so they decide to set up an experiment. They start by taking a 100.0 mL flask containing an aqueous solution of 5210. mg/L Cr3+ and adding 50.0 mL of an aqueous 2.0 M MgO solution to precipitate the heavy metal from the solution.
2. Write the net ionic equation for this reaction. What is/are the spectator ion(s) in this reaction?

Net ionic equation:

**Answer: 2 Cr3+ (aq) + 3 O2− (aq) → Cr2O3 (s)**

Spectator(s):

**Answer: Mg2+**

**Instructor Note: Parts B and C can be removed if ion concentration after reaction is not covered in the course or for time, as they are time intensive problems.**

1. What is the concentration of Cr3+, Mg2+, and O2− (in M) after the reaction is complete? Answer each ion in three significant figures.

Cr3+ =

**Answer: 0.00 M**

O2− =

**Answer: 0.566 M**

Mg2+ =

**Answer: 0.667 M**

1. To the same reaction flask, after the oxide has reacted completely, Parker adds an additional 900.0 mL of an aqueous solution of 4500.0 mg/L Cr3+. What is the concentration of Cr3+, Mg2+, and O2− (in M) after the reaction is complete? Answer each ion in three significant figures.

Cr3+ =

**Answer: 0.0202 M**

O2− =

**Answer: 0.00 M**

Mg2+ =

**Answer: 0.0952 M**

1. The amount of precipitate that forms (i.e. sludge) is a common concern when using chemical precipitation in water remediation. One of Parker’s objectives is determining ways of reducing the amount of sludge that must be disposed of, while also trying to remove as much pollutant as possible. One of the common ions Parker studies in water remediation is Cu2+, which they know can be readily precipitated with Li2S, Li2CO3, or Na2CO3.

Which chemical above will produce the smallest amount of sludge (by mass) while also precipitating the maximum amount of Cu2+?

**Instructor Note: A hint can be added to this question, like “how could you tell what the mass will be for the same amount of moles?”**

**Answer: Li2S, based on molar mass of CuS vs CuCO3**

1. Another consideration when choosing between Li2S, Li2CO3, or Na2CO3 is the cost of each. The plant Parker works at is contracted with a manufacturer who offers the following compounds at different costs shown in the table below.

|  |  |  |
| --- | --- | --- |
| **Compound** | **Cost** | **Package Size** |
| Li2S | $234.08 | 10.0 g |
| Li2CO3 | $38.72 | 100.0 g |
| Na2CO3 | $188.32 | 500.0 g |

Which of the following compounds would be the cheapest in remediating the Cu2+ solution in the previous question?

**Instructor Note: A hint can be added to this question, like “how could you tell how much reactant you will need to use? Could you compare the cost based on remediating 100. g of Cu2+?”**

**Answer: Li2CO3, based on the amount of reactant needed based on the stoichiometry and theoretical yield**

1. The water remediation plant Parker works at treats, on average, 3.75 million gallons of water per day. The water has an average concentration of 45.0 mg/L Cu2+, and it is treated every day in a standard calendar year (365 days). 1 gallon = 3.785 L

**Instructor Note: This question may be removed for time or because of the difficulty.**

1. How many moles of Cu2+ require treatment per day? How many per year?

Per day =

**Answer: 1.01 × 104 moles**

Per year =

**Answer: 3.67 × 106 moles**

1. In question 6, you determined the chemical that would produce the smallest amount of precipitate when treating Cu2+. Use that same chemical in this question to determine how much precipitate would be produced per day (in pounds). How much precipitate is produced per year (in pounds)? 1 pound = 453.59 g

Per day =

**Answer: 1.02 × 103 moles**

Per year =

**Answer: 3.72 × 105 moles**

1. In question 7, you determined which chemical would be the cheapest when treating Cu2+. Use that same chemical in this question to determine the cost to treat this water per day (in dollars). What is the cost per year?

Per day =

**Answer: 2.88 × 105 moles**

Per year =

**Answer: 1.05 × 108 moles**

1. In questions 6-7, you helped Parker compare the use of different chemicals based on two main factors: (1) the amount of precipitate that would form and (2) the cost of the chemicals used.

What other factors should Parker have considered? Can you think of any other costs that should be considered? What about other concerns? Answer this question listing at least 2 potential concerns.

**Answer: multiple answers could be accepted here, including:**

**-Cost/labor of removing precipitate/sludge**

**-Hazardous waste concerns of different precipitates**

**-Safety concerns using different chemicals**

**-Degree of solubility of different precipitates**

**-Presence of other ions in the water and competing reactions as a result**

# Works Cited

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(2) Tesh, S. J.; Scott, T. B. Nano-Composites for Water Remediation: A Review. *Adv. Mater.* **2014**, *26*, 6056–6068. DOI: 10.1002/adma.201401376

(3) UNW-DPAC, UN Report: Water and industry in the green economy: Information brief, **2011**.

(4) Pohl, A. Removal of Heavy Metal Ions from Water and Wastewaters by Sulfur-Containing Precipitation Agents. *Water Air Soil Pollut.* **2020**, *231*, 503. DOI: 10.1007/s11270-020-04863-w.

(5) United States Environmental Protection Agency, Wastewater Technology Fact Sheet Chemical Precipitation. EPA 832-F-00-018. **2020**.

(6) Akpor, O.B.; Muchie, M.; Remediation of Heavy Metals in Drinking Water and Wastewater Treatment Systems: Processes and Applications. *Int. J. Phys. Sci.* **2010**, *5*, 1807–1817.

(7) Fu, F.; Wang, Q. Removal of Heavy Metal Ions from Wastewaters: A Review. *J. Environ. Manage.* **2011**, *92*, 407–418. DOI: 10.1016/j.jenvman.2010.11.011.