Chemical Remediation of Nickel (II) Waste: A Laboratory Experiment for General Chemistry Students

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Instructor Notes:

The experiment is designed for a typical course where students have lab once per week. To adapt the experiment for more or less frequent lab periods, the procedure wrap-up can be done at any time after the nickel hydroxide has had sufficient drying time.

Each student will need:

- A solution of nickel sulfate in water (4 g in 260 mL of water was used in our laboratory.)
- An appropriate amount of 1M NaOH to react completely with the nickel sulfate (31 mL of 1M NaOH was used in our laboratory.)
- pH paper
- Large (400 mL) beaker
- Weigh boat
- Analytical balance

If vacuum filtration is to be used:

- Filter paper
- Buchner funnel and rubber stopper
- Erlenmeyer with a side-arm for filtration (500 mL)
- Ring stand and clamp
- Vacuum tubing
- Water aspirator or house vacuum adapter

If gravity filtration is to be used:

- Filter paper
- Funnel
- Erlenmeyer flask (500 mL)

Additional: Large waste container for the class

The experiment relies upon a solution of 4 g of nickel sulfate in 260 mL of water from a previous Beer's Law experiment (*1*). This procedure could be performed to follow this experiment or any experiment using a solution of nickel (II) ions where it is desirable to recover the metal. If a different amount of nickel sulfate solution is used, the stoichiometric amount of 1M NaOH can be altered according to the following equations:

$$NiSO_{4(s)} \longrightarrow Ni^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \quad (1)$$

$$Ni^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 2Na^{+}_{(aq)} + 2OH^{-}_{(aq)} \longrightarrow Ni(OH)_2 \times H_2O_{(s)} + 2Na^{+}_{(aq)} + SO_4^{2-}{}_{(aq)} \quad (2)$$

If the pH of the student's solution does not indicate basicity (as described in step 3 of the student procedure), more 1M NaOH solution can be added dropwise to achieve the desired pH.

If gravity filtration is to be used instead of vacuum filtration (step 5 of the student procedure), students should fan-fold a piece of filter paper to place in a funnel and slowly pour the solution into the filter paper. Once the liquid has passed through, students can keep slowly adding more of the solution until it has all been filtered.

If students have adequately filtered their solutions, the liquid remaining can be dumped down the sink. If there is doubt about the sufficiency of the filtering step, a second filtration can be conducted.

CAS:

10101-97-0 Nickel sulfate hexahydrate

36897-37-7 Nickel hydroxide monohydrate

Hazards:

The experiment contains no chemical hazards. Nickel compounds are considered suspected cancer agents via inhalation, but exposure is not expected in this experiment. Additionally, nickel hydroxide substances do not cause chemical burns or other problems that harsher hydroxides can. A 2005 *J. Chem. Educ.* letter addresses these concerns and points out appropriate literature (*2*).

Literature Cited in Lab Documentation

1. Mercer University Department of Chemistry Laboratory. h*ttp://chemistry.mercer.edu/genchem/chm111.htm* (accessed July 2008).

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Student Instructions:

Procedure – Week 1

1. Remove from your lab drawer the container of the approximate 260 mL of nickel solution from the Beer's Law experiment. Gently swirl it to ensure a homogenous mixture.
2. Measure 31 mL of 1M NaOH into your 50-mL graduated cylinder. Add the NaOH solution to the nickel waste solution and swirl gently.
3. Measure the pH of the solution using pH paper to ensure that the pH is 11. If it is not, see your lab instructor.
4. Let the solution set for approximately 10 minutes and some of the nickel precipitate will settle to the bottom of the brown glass bottle. Carefully decant as much of the water layer as you can into a large beaker, being sure to not decant any of the solid green nickel precipitate. Pour the water from the beaker into the container marked "Liquid Nickel Waste."
5. Set up the vacuum filtration apparatus according to the following:
    a.) Get a piece of filter paper large enough to cover all of the holes in the bottom of the Buchner funnel and yet to not curl up the sides of the funnel. It is placed flat against the bottom of the funnel.
    b.) Clamp a 500-mL filter flask to a ring stand. Place a rubber stopper into the top of the filter flask and place the Buchner funnel into it. (The Buchner funnel makes the setup top-heavy and prone to tipping over. Ensure that the flask is clamped before adding the rubber stopper and Buchner funnel.)
    c.) Attach a piece of heavy-walled tubing to the side arm on the neck of the filter flask. Connect the other end of the heavy-walled tubing to the horizontal adapter of the water aspirator on the sink.
    d.) Turn on the faucet of the water aspirator full blast. This should suck down the filter paper. You may have to push down on the Buchner funnel a bit to get a good seal between the rubber adapter and the funnel.

6. Now you are ready to filter. Swirl the contents of the brown glass bottle and slowly pour the solution into the center of the filter paper. Slowly! Don't flood the funnel by filling it up to the brim and waiting for the level to go down, as you could ruin the setup.
7. Once all of the solution has been poured through the funnel, leave the aspirator on and let air pass through the crystals to help them dry.
8. Turn off the water aspirator. Remove the Buchner funnel and turn it upside down over the weigh boat. The filter paper should fall out onto the weigh boat. Scrape the nickel hydroxide solid from the filter paper into the weigh boat, being careful to not scrape off pieces of the filter paper. Place the filter paper on the side of the weigh boat. Place the weigh boat in the lab drawer so that the crystals can dry for the next week.
9. The liquid waste that remains in the 500-mL filter flask can be poured into the container marked "Liquid Nickel Waste."

Procedure Wrap-up– Week 2

Obtain the mass of the crystals recovered. Calculate the % yield.

Sample Pre-lab:

1. How many mol of nickel are present in 4.0000 g of nickel (II) sulfate hexahydrate?
2. Balance the equation below:

   $Ni^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + NaOH_{(aq)} + H_2O \rightarrow Ni(OH)_2 \times H_2O_{(s)} + SO_42-_{(aq)} + Na+_{(aq)}$

3. How many grams of nickel (II) hydroxide monohydrate should be produced based upon the number you calculated in #1?

Sample Post-lab:

1. Report the grams of nickel (II) hydroxide monohydrate recovered.
2. Report the theoretical yield.
3. Report the percent yield.