



Passage II

A high concentration of *dissolved nickel* (Ni^{2+}) in wastewater is an environmental concern. Students studied the removal of Ni^{2+} from wastewater, using an aqueous Ni^{2+} solution as a model of wastewater.

In water, hydroxide (OH^-) reacts with Ni^{2+} to form nickel hydroxide monohydrate $[\text{Ni}(\text{OH})_2 \cdot \text{H}_2\text{O}]$. The balanced chemical equation for this reaction is



Because the monohydrate is a solid, it can be filtered from the solution. Some of the solid will eventually dissolve if it is left in contact with the solution.

The students did 2 experiments to study how reaction time and filtration method affected the removal of Ni^{2+} from the aqueous Ni^{2+} solution.

Experiment 1

In each of Trials 1–3, Steps 1–4 were performed:

1. Thirty-two mL of aqueous 1.0 mole/L OH^- solution and 260 mL of aqueous 0.060 mole/L Ni^{2+} solution were poured into the same flask.
2. The mixture was stirred at 22°C for 10 min, 3 days, or 7 days.
3. Solid monohydrate was recovered by *standard filtration* (see Figure 1).

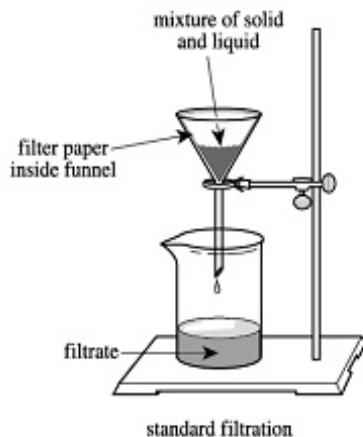


Figure 1

4. The *concentration of Ni^{2+} in the filtrate*, CNF, was determined, in milligrams of Ni^{2+} per kilogram of solution (mg/kg).

Experiment 2

In each of Trials 4–6, Steps 1–4 in Experiment 1 were performed except that in Step 3, solid monohydrate was recovered by *vacuum filtration* (see Figure 2).

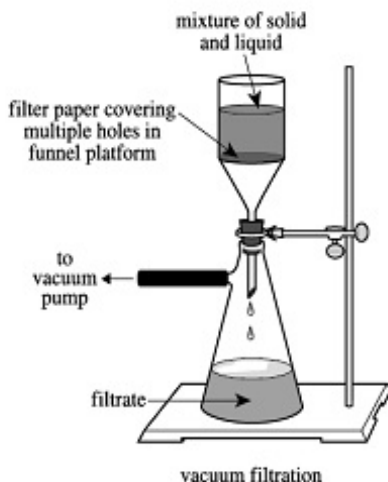


Figure 2

The results of Experiments 1 and 2 are shown in Table 1.

Experiment	Trial	Reaction time	CNF (mg/kg)
1	1	10 min	6
	2	3 days	39
	3	7 days	42
2	4	10 min	58
	5	3 days	69
	6	7 days	73

Table 1 adapted from K. Blake Corcoran, Brian E. Rood, and Bridget G. Trogden, "Chemical Remediation of Nickel(II) Waste: A Laboratory Experiment for General Chemistry Students." ©2010 by Division of Chemical Education, Inc., American Chemical Society.

7. If a reaction time of 2 days had been tested in Experiment 1, the CNF would most likely have been:
 - A. less than 6 mg/kg.
 - B. between 6 mg/kg and 39 mg/kg.
 - C. between 39 mg/kg and 42 mg/kg.
 - D. greater than 42 mg/kg.

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8. Based on the results of Experiments 1 and 2, what combination of reaction time and filtration method resulted in the lowest concentration of dissolved nickel in the filtrate?

	reaction time	filtration method
F.	10 min	standard
G.	7 days	standard
H.	10 min	vacuum
J.	7 days	vacuum

9. Was the net force exerted on the mixture in the funnel more likely greater in Trial 3 or in Trial 6?
- A. Trial 3, because the filtration apparatus was connected to a vacuum pump.
 B. Trial 3, because the filtration apparatus was not connected to a vacuum pump.
 C. Trial 6, because the filtration apparatus was connected to a vacuum pump.
 D. Trial 6, because the filtration apparatus was not connected to a vacuum pump.
10. In each trial, the students performed which of the following chronological sequences of steps?
- F. Measuring the CNF; recovering the solid by filtration; mixing the Ni^{2+} and the OH^- solutions
 G. Mixing the Ni^{2+} and the OH^- solutions; recovering the solid by filtration; measuring the CNF
 H. Recovering the solid by filtration; measuring the CNF; mixing the Ni^{2+} and the OH^- solutions
 J. Recovering the solid by filtration; mixing the Ni^{2+} and the OH^- solutions; measuring the CNF
11. A student predicted that when solid monohydrate is recovered by vacuum filtration, a greater CNF will result for a reaction time of 3 days than for a reaction time of 10 min. Do the data in Table 1 support this prediction?
- A. No; Trial 1 had a greater CNF than did Trial 2.
 B. No; Trial 5 had a greater CNF than did Trial 4.
 C. Yes; Trial 1 had a greater CNF than did Trial 2.
 D. Yes; Trial 5 had a greater CNF than did Trial 4.
12. In how many of the 6 trials was nickel hydroxide monohydrate recovered by standard filtration after OH^- and Ni^{2+} had been allowed to react for at least 3 days?
- F. 1
 G. 2
 H. 4
 J. 6
13. Based on the balanced chemical equation in the passage, as 6 OH^- ions are consumed, how many formula units of $\text{Ni}(\text{OH})_2 \cdot \text{H}_2\text{O}$ are produced?
- A. 3
 B. 6
 C. 12
 D. 18