Microscale activity: Filling a 50 cm^3 syringe with hydrogen

Concepts being developed: Limiting reagents

The simplest method is to use a hydrogen cylinder or canister; however, this is expensive.

The chemical method to fill a syringe with hydrogen by Bruce Mattson[1] is a good exercise in understanding the limiting reagent in a reaction. The reaction between magnesium and dilute hydrochloric acid is used for making hydrogen, and the equation is as follows:

$$Mg(s) + 2HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$$

60 cm^3 of any gas at room temperature and pressure contains 60/24000 or 0.00208 mol of molecules. Since the atomic mass of magnesium is 24 g mol^{-1}, the minimum mass of magnesium required is 0.050 g. Using the balanced equation, the minimum amount of acid required would 0.00416 mmol. To produce 60 cm^3 of hydrogen, a minimum of volume of 4.16 cm^3 of 1 M hydrochloric acid is required.

In the Bruce Mattson method, magnesium is the limiting reagent and an excess volume of acid is used.

The availability of the plastic 3-way tap provides an alternative version with the acid as the limiting reagent[2]. The reaction is exothermic. The technique can be used to make carbon dioxide and oxygen in convenient volumes from 20 to 60 cm^3.

Ensure that full planning and risk assessment is carried out before attempting this activity. Students operating the syringe may need to wear disposable gloves. Practice with water to make sure that you know how to turn the tap so that the liquid to be added from a smaller syringe, moves directly into the larger syringe and vice versa.

Outline requirements

Suggested apparatus and materials (per student group)

- Magnesium ribbon
- 2 M hydrochloric acid
- 50-60 cm^3 syringe to collect the gas
- 5 cm^3 syringe
- Syringe caps
- 3-way taps

Outline method

1. Weigh 0.06 to 0.07 g of magnesium ribbon and place it in the barrel of a 60-cm^3 plastic syringe. Push the plunger down as far as it will go to minimise the volume of air in the syringe.
2. Draw up into a 5 cm^3 syringe, 2.2 cm^3 of 2 M hydrochloric acid or 4.2 cm^3 of 1 M hydrochloric acid. (The syringe is divided into 0.2 cm^3 divisions, so the next division mark after the calculated value is used for the volume.)
3. Attach these syringes to the 3-way tap fitted with a cap.
4. Push the acid from the small syringe into the larger syringe and watch the plunger rise as the gas is evolved. A little agitation is sometimes required.
5. Push the remaining liquid back into the smaller syringe.
6. Remove the large syringe of hydrogen and add a cap.
7. Remove the small syringe from the tap and dispose of the liquid into the sink.
8. Attach a dry, closed 60-cm^3 syringe to the tap, attach the wet hydrogen just prepared and transfer this gas into the dry syringe. Label the syringe.

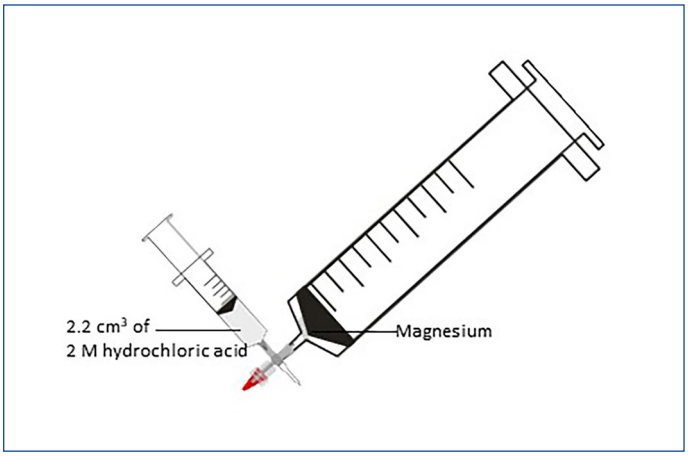

Figure 1 Diagrammatic set-up for filling a syringe with gas.

Figure 2 Filling a 2 cm^3 syringe with hydrogen. In this case, the acid is added with a 1 cm^3 syringe on the left.

Teacher activities

1. The Bruce Mattson Microscale Gas chemistry site is a comprehensive account of the chemistry of gases. You can download a book of his elementary gases and see just how far he takes this method of gas chemistry.
2. Oxygen and carbon dioxide can be made by this procedure.

Carbon dioxide

The gas can be made from anhydrous sodium carbonate, which is inserted into the bottom of the syringe (with a long spoon/spatula if the syringe is wet). The smaller syringe contains the required volume of 1 or 2 M hydrochloric acid.

Oxygen

The gas can be made from about 0.1 g of solid potassium iodide (a catalyst), which is inserted into the bottom of the syringe (with a long spoon/spatula if the syringe is wet). The smaller syringe contains the required volume of 20 vol hydrogen peroxide. The reaction is slower than for the other two gases.

References

[1]http://mattson.creighton.edu/Gas_Book_Web_Version_2017/Microscale%20Gas%20Chemistry%202017%20Web%20Edition%20Download%20Agree%20Page%20Group%200.html. This must be one of the best sites of microscale chemistry to be found. Here is Chad Husting showing how it is done in a video https://youtu.be/suvoERrVhPM.

[2]http://mattson.creighton.edu/Microscale_Gas_Chemistry.html