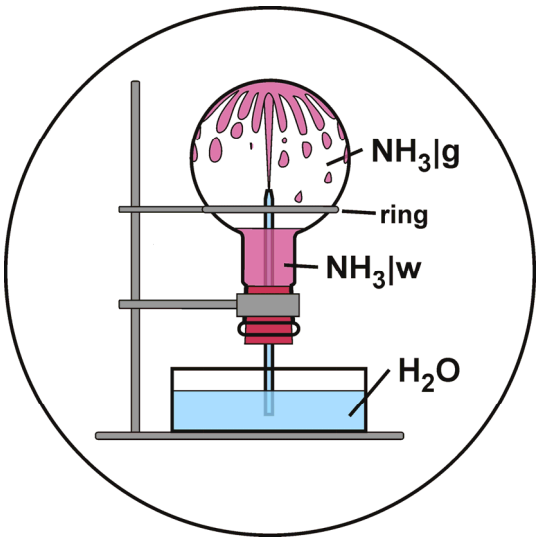
Ammonia Fountain



Equipment:

2-L round-bottomed flask
dropping funnel
250-mL round-bottomed flask with two necks
for dropping funnel and glas tube
glass tube (diameter: 7–8 mm)
L-shaped glass tube (diameter: 7–8 mm)
flexible rubber hose
ring stands, clamps and ring
glass tube with tapered end
(length: approx. 30 cm, diameter: 7–8 mm)
two rubber stoppers with one hole and one with two holes
small rubber stopper (that fits the glass tube)
crystallization dish or beaker
blow-dryer

Chemicals:

concentrated ammonia solution
sodium hydroxide pellets
deionized water
phenolphthalein solution (in ethanol)
diluted hydrochloric acid

Safety:

concentrated ammonia solution (NH_3):

H314, H400
P273, P280, P305 + P351 + P338, P309, P310

sodium hydroxide (NaOH):

H314, H290
P280, P301 + P330 + P331, P309 + P310, P305 + P351 + P338

phenolphthalein solution ($C_{12}H_{14}O_4$) (in ethanol):

H226, H350, H341
P201, P210, P233, P281, P308 + P313

Ammonia is a colorless, highly corrosive and irritant gas which is especially harmful to the respiratory system and the eyes. Therefore, the round-bottomed flask has to be filled in a fume hood. It is also necessary to wear safety glasses and protective gloves.
To avoid implosion-related incidents caused by the stress of the vacuum created during the experiment damaged glassware (with “stars”, cracks etc.) should never be used.

Procedure:

Preparation: A relatively dry sample of ammonia gas can be prepared by dropping concentrated ammonia solution onto granular sodium hydroxide. Therefore, 15 g of NaOH

pellets are put into the 250-mL round-bottomed flask with two necks. The dropping funnel is attached to one neck, and the second neck is closed using a one-hole rubber stopper with a glass tube in it. The 2-L round bottomed flask is closed using a two-hole rubber stopper with an L-shaped glass tube in one of the holes and the other hole open. The 2-L flask is mounted upside-down to a stand, and a flexible rubber hose is used to connect the glass tubes of the two flasks together.
The dropping funnel is filled with 30 mL concentrated ammonia solution that is dripped into the 250-mL flask. The developed dry ammonia gas fills the 2L-flask by downward displacement of air. After the reaction, the 2-L flask is sealed with a one-hole stopper that has the tapered glass tube in it. The tapered end should be inside the flask, and extend about half of the way into the bulb. The flask is heated by a blow-dryer and subsequently, the non-tapered end of the glass tube is sealed with a small rubber stopper.
Procedure: The crystallization dish is filled with deionized water, and the indicator phenolphthalein and a few drops of hydrochloric acid are added to the water. The inverted 2L-flask is clamped on the stand over the crystallization dish so that the bottom end of the glass tube is immersed deeply in the water and secured by a ring. Then the small rubber stopper is removed.

Observation:

The water begins to rush up in the glass tube because of slight underpressure in the flask. After the first drops have entered the flask the speed of the process increases more and more until the water shoots into the flask like a fountain. Additionally, the solution turns pink. The water level rises until the flask is nearly completely filled.

Explanation:

Ammonia gas is extremely soluble in water (1 L of water can dissolve 702 L of ammonia gas at 20 °C!). The fountain experiment demonstrates the violence with which ammonia is absorbed by water. The process can be explained thermodynamically by use of the chemical potential:

$$\begin{array}{lcl} & \mathrm{NH_3|g \rightarrow NH_3|w} & \\ \hline \mu^{\ominus}: & -16.5 \;>\; -26.6 & \text{kG} \end{array}$$

$$\Rightarrow \text{chemical drive } \mathcal{A}^{\ominus}: +10.1 \text{ kG}$$

The chemical drive of the reaction is positive, i.e. the reaction takes place spontaneously.

The first few water drops that enter the round-bottomed flask dissolve part of the ammonia gas, thereby reducing its volume considerably. This causes a decrease in pressure in the flask, and more water is drawn from the reservoir into it. As more and more water rushes into the flask, more and more of the ammonia gas dissolves creating a larger pressure difference, thereby speeding up the flow of the water.

The aqueous ammonia solution is a weak base because of the protolysis reaction:

$$\mathrm{NH_3 + H_2O \rightarrow NH_4^+ + OH^-}.$$

This alkaline effect of ammonia is revealed by the indicator phenolphthalein, which changes its color to pink.

Disposal:

The solution is neutralized with hydrochloric acid and poured down the drain.