Making silicon and silanes from sand

Description

Magnesium and sand are heated together and silicon is produced by an exothermic reaction. The product is placed in acid to remove magnesium oxide and unreacted magnesium. Small amounts of silanes are produced by the reaction of magnesium silicide (a side product) with the acid. These react spontaneously with air to give spectacular but harmless small explosions.

This experiment should take around 5-10 minutes.

Apparatus and chemicals

- Eye protection
- Safety screen
- One pyrex test-tube, approximately 150 mm x 17 mm
- Clamp and stand
- Bunsen burner
- One 250 cm^3 beaker
- One 250 cm^3 conical flask
- Filter funnel and filter paper.
- Access to oven
- Desiccator
- Access to top pan balance.

The quantities given are for one demonstration.

- 1 g of dry magnesium powder (**Highly flammable**)
- 1 g of dry silver sand
- About 50 cm^3 of approximately 2 mol dm^{-3} hydrochloric acid

Technical notes

Magnesium powder (**Highly flammable**). Refer to SSERC or CLEAPSS Hazcards.

Dilute hydrochloric acid (**Irritant** at concentration used). Refer to SSERC or CLEAPSS Recipe and Hazcards .

Procedure

Health & Safety: Wear safety goggles. Use a safety screen between the apparatus and the audience.

Magnesium powder burns vigorously in air. The dust from magnesium powder may be hazardous. Ensure that the mixed powders are absolutely dry before the reaction.

It is the responsibility of the teacher to check the employer's risk assessment.

Before the demonstration

a It is important that the reactants are dry. Dry the magnesium powder and the sand for a few hours in an oven at about 100 °C. Store them in the desiccator until ready to use them. Ensure that the test-tube is dry.

The demonstration

b Weigh 1 g of silver sand and 1 g of magnesium powder and mix them thoroughly. This mixture has a small excess of magnesium over the stoichiometric masses (1 g of sand to 0.8 g of magnesium) because some magnesium will inevitably react with air. Spread the mixture along the bottom of a test-tube that is clamped almost horizontally. Place a safety screen between the tube and the audience if the spectators are close.

c Heat one end of the mixture with a roaring Bunsen flame, holding the burner by hand. After a few seconds the mixture will start to glow. This glow can be 'chased' along the tube with the flame until all the mixture has reacted. The tube will blacken and partly melt. If the two powders are not dry, some magnesium will react with the steam and the resulting hydrogen will pop. This can be disconcerting if it is not expected.

d When the reaction is complete, allow the mixture to cool (about five minutes) and with the aid of a spatula pour the products into about 50 cm^3 of 2 mol dm^{-3} hydrochloric acid. The solid will contain silicon, magnesium oxide (the main products), magnesium silicide formed from the reaction of excess magnesium with silicon, unreacted magnesium and possibly a little unreacted sand. The mixture will fizz as excess magnesium reacts with the acid. There will also be pops accompanied by small yellow flames. These are caused by silanes that are formed from the reaction of magnesium silicide with acid. Silanes inflame spontaneously in air. Magnesium oxide will react with the acid to form a solution of magnesium chloride.

e After a few minutes the pops will cease and grey silicon powder, possibly with a little unreacted sand, will be left on the bottom of the beaker. Pour off the acid, wash the solid a few times with water and filter off the silicon. It can be passed around the class to show its slightly metallic silver-grey colour. If desired show that it does not react with alkalis (or acids).

Visual tips

Make sure the safety screen is clean.

Teaching notes

There are many interesting contrasts to be drawn between silicon compounds and their carbon analogues. Silicon dioxide is a solid with a giant structure, while carbon dioxide is molecular. Silanes react spontaneously with air at room temperature while alkanes are stable. These differences can be explained by considering the relevant bond energies and availability of d-orbitals in silicon but not in carbon.

Bond energies in kJ mol^{-1}: Si=O 638; Si–O 466; C– O 336; C=O 805; Si–H 318; C– H 413.

Theory

The reactions are:

$SiO_2(s) + 2Mg(s) \rightarrow 2MgO(s) + Si(s)$

$2Mg(s) + Si(s) \rightarrow Mg_2Si(s)$

$MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$

$Mg_2Si(s) + 4HCl(aq) \rightarrow 2MgCl_2(aq) + SiH_4(g)$

(Higher silanes such as Si_2H_6 may also be produced.)

$SiH_4(g) + 2O_2(g) \rightarrow SiO_2(s) + 2H_2O(l)$

Further details

One teacher reported that the ‘pops’ continued while the silicon dried on the filter paper.

Silicon is extracted from sand industrially by reduction with carbon.

Reference

This experiment has been adapted from *Classic Chemistry Demonstrations*, Royal Society of Chemistry, London, p.127-129

Credits

Health & safety checked January 2018

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