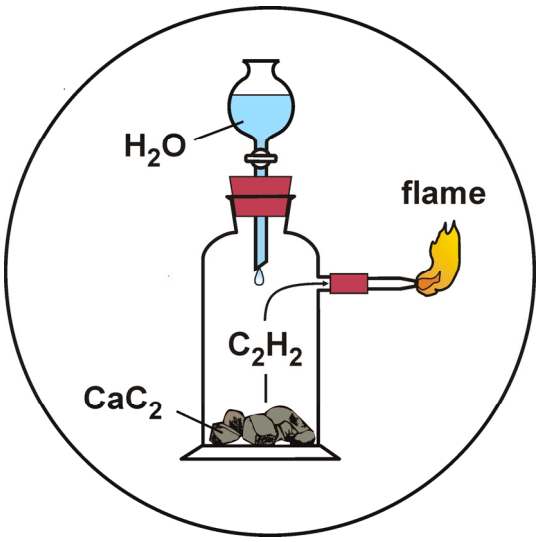
Carbide Lamp



Equipment:

washing bottle with dropping funnel
rubber hose
glass tube with tapered end
matches or pocket lighter
wooden splint
test tube

Chemicals:

calcium carbide (ideal grain size: 20 – 40 mm)
deionized water

Safety:

calcium carbide (CaC_2):

H260
P223, P231 + P232, P370 + P378, P422

ethyne (acetylene) (C_2H_2):

H220
P210

calcium hydroxide ($Ca(OH)_2$):

H318
P280, P305 + P351 + P338, P313

Ethyne is extemely flammable and forms explosive mixtures with air (“detonating gas”). Because the gas is poisonous particularly with regard to contaminants it is necessary to work in a fume hood. It is also required to wear safety glasses and protective gloves.

Procedure:

The dropping funnel is filled with water and some lumps of calcium carbide are placed in the washing bottle. Water is dripped (**cautiously!**) onto the calcium carbide until a vigorous generation of gas begins. Then the cock of the dropping funnel is closed and the escaping gas is collected in the test tube. The existence of an explosive mixture can be tested by ignition with a burning splint. When the explosion danger is overcome, i.e. most of the air in the washing bottle is displaced by ethyne, the gas can be ignited directly at the tapered end of the glass tube by the splint (eventually, it is necessary to drip again some water onto the carbide). For avoiding any explosion danger it is recommended to fill the washing bottle with nitrogen before starting the experiment.

Observation:

The produced gaseous ethyne burns with a bright and sooty flame. Additionally, an unpleasant garlic-like odor can be noticed.

Explanation:

As the calcium carbide reacts with water it produces ethyne (acetylene) according to

$$CaC_2|s + 2\ H_2O|l \rightarrow Ca(OH)_2|s + C_2H_2|g$$

$\Sigma\mu^{\ominus}$: **–**538.8 **>** **–**688.3 kG

$\Longrightarrow$ chemical drive $\mathcal{A}^{\ominus}$: **+**149.5 kG

The drive of the reaction is positive, i.e. the reactants combined have a higher chemical potential than the products and subsequently, the reaction takes place spontaneously.

Necessary chemical potentials ($T^{\ominus}$ = 298 K, $p^{\ominus}$ = 100 kPa):

Substance	Chemical potential $\mu^{\ominus}$ [kG]
$CaC_2\|s$	**–**64.6
$H_2O\|l$	**–**237.1
$Ca(OH)_2\|s$	**–**898.2
$C_2H_2\|g$	+209.9

The very low chemical potential of calcium hydroxide on the product side makes sure that a potential drop between the reactants and the products exists, even though the chemical potential μ of ethyne exceeds 0.

A positive chemical potential, like in the case of ethyne, therefore does not mean that the substance cannot be produced by normal reactions of stable substances (with negative μ). It only means that the substance tends to decompose into its elements (however, this process might proceed very slowly because of inhibitions, like in the case of benzene).

The “burning test” demonstrates that the produced ethyne reacts with oxgen in the air describable by

$$2\ C_2H_2|g + 5\ O_2|g \rightarrow 4\ CO_2|g + 2\ H_2O|l.$$

In earlier times, the gas extracted from the above reaction was used to power miners’ lamps and bicycle lights because of its bright flame. It is still used today for welding because of its high combustion temperature.

The characteristic “carbide odor”, however, is not caused by ethyne but by the toxic gas phospine released by the contaminant calcium phosphide on contact with water.

Pure calcium carbide forms colorless, transparent crystals. Mostly the technical product is commercially available which is composed of grayish black or brown lumps. The color is caused by contamination with carbon and iron oxide. Other contaminants are calcium oxide, calcium phosphide mentioned above, calcium sulfide, calcium nitride and silicium carbide.

Disposal:

After the burning of the produced ethyne, the residue should completely react with water in the fume hood. The produced solution of calcium hydroxide is neutralized and flushed down the drain with water.