



Oxford Cambridge and RSA

**Monday 19 June 2023 – Afternoon**

**A Level Chemistry B (Salters)**

**H433/02** Scientific literacy in chemistry

Advance Notice Article

**Time allowed: 2 hours 15 minutes**



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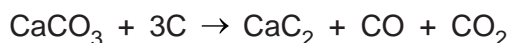
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## Calcium Carbide

Adapted from: Group 14 (C, Si, Ge, Sn, and Pb) Alkaline Earth Compounds by R.C. Ropp, in Encyclopedia of the Alkaline Earth Compounds, 2013, Elsevier

Calcium carbide has the nominal formula of  $\text{CaC}_2$  and the molecular weight of 64.0992 g/mol. The pure material is colorless, but most samples have a color ranging from black to greyish-white, depending on the grade. Its density is 2.22 g/cc and it melts at 2160 °C with a boiling point (under an inert atmosphere) of 2300 °C, where it decomposes. Its main use industrially is in the production of acetylene (ethyne) and calcium cyanamide,  $\text{CaCN}_2$ . Calcium carbide is produced industrially in an electric-arc furnace from a mixture of  $\text{CaCO}_3$  and coke (carbon) at approximately 2000 °C. This method has not changed since its invention in 1888:

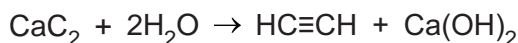


The high temperature required for this reaction is not practically achievable by traditional combustion, so the reaction is performed in an electric-arc furnace where the electrodes are graphite. The carbide product produced generally contains around 80–85% calcium carbide by weight. The carbide is crushed to produce small lumps that can range from a few millimeters up to 50 mm. The impurities are concentrated in the finer fractions. The  $\text{CaC}_2$  content of the product is assayed by measuring the amount of acetylene produced on hydrolysis. As an example, the U.S. standard for the content of the coarser fractions is 295–300 //kg. Impurities present in the carbide include phosphide, which produces  $\text{PH}_3$  (a poisonous gas) when the  $\text{CaC}_2$  is hydrolyzed to produce  $\text{HC}\equiv\text{CH}$ , i.e. acetylene.

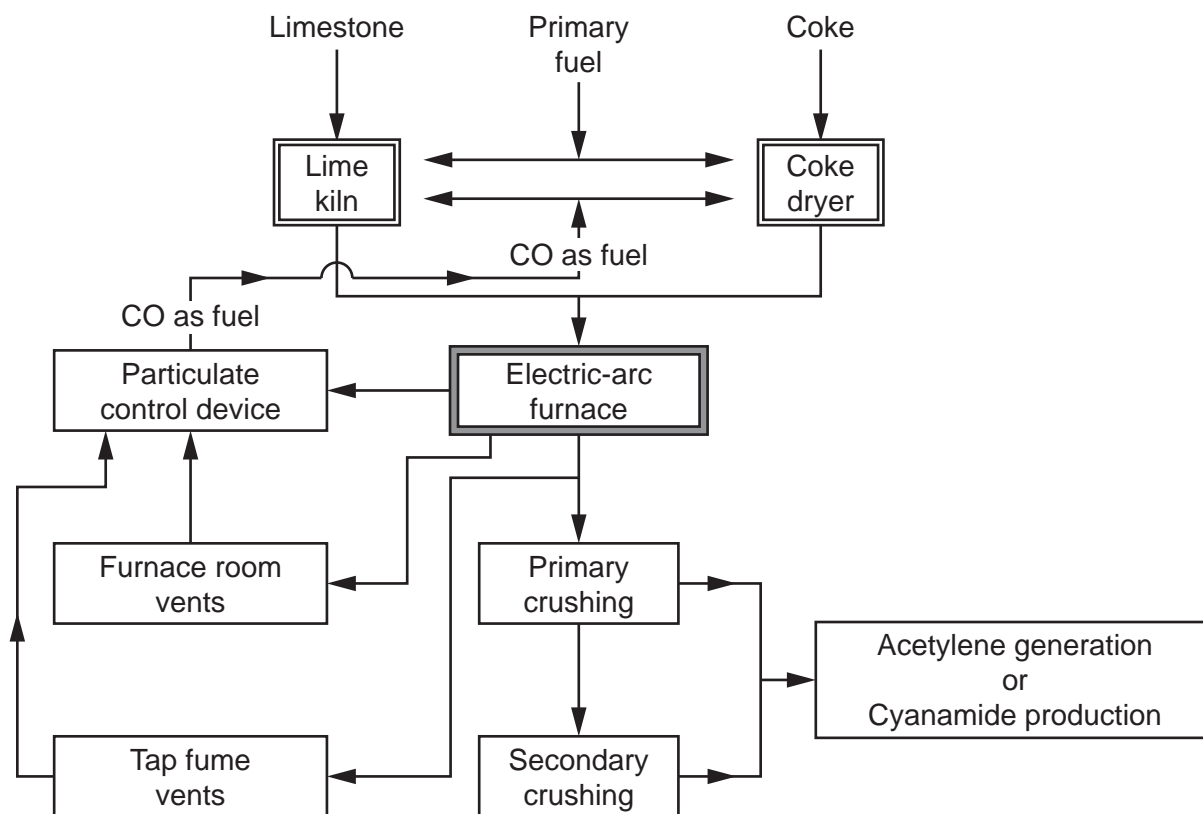
This reaction was an important part of the industrial revolution in chemistry, and was made possible in the U.S. as a product of massive amounts of cheap hydroelectric power generated at Niagara Falls before the turn of the twentieth century. The method for the production of  $\text{CaC}_2$  in an electric-arc furnace was discovered independently by two researchers in Europe in 1888 and 1892. **Fig. 1** is an illustration of how  $\text{CaC}_2$  has been manufactured.

The common crystalline form at room temperature is a distorted rock salt structure with the  $\text{C}_2^{2-}$  units lying parallel. In calcium carbide,  $\text{CaC}_2$ , the  $\text{C}\equiv\text{C}$  triple bond length is about 1.092 Å (similar to ethyne).

This reaction is the basis of the industrial manufacture of acetylene, and is the major industrial use of calcium carbide in industrial circles:

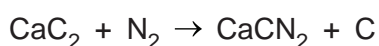


**Fig. 1 Industrial Process for Producing Calcium Carbide**



In China, acetylene derived from calcium carbide remains a raw material for their chemical industry, in particular for the production of polyvinyl chloride. Locally produced acetylene is more economical than using imported oil. Production of calcium carbide in China has been increasing. In 2005, output was 8.94 million tons, with the capacity to produce 17 million tons. In the USA, Europe and Japan consumption is generally declining. Production levels in the USA in the 1990s were 236 000 tons per year.

Calcium carbide reacts with nitrogen at high temperature to form calcium cyanamide:



Calcium cyanamide is used as fertilizer. It is hydrolyzed to cyanamide,  $\text{H}_2\text{N}-\text{C}\equiv\text{N}$ , in the soil and is readily available to plants as a nitrogen plant food.

Calcium carbide was used in carbide lamps, in which water drips on the carbide and the acetylene formed is ignited. These lamps were usable but dangerous in coal mines, where the presence of the flammable gas methane made them a serious hazard. The presence of flammable gases in coal mines led to the miner "safety lamp". However, carbide lamps were used extensively in slate, copper and tin mines, where methane is less likely, but most have now been replaced by electric lamps. They were also used extensively as headlights in early automobiles, motorcycles and bicycles, although in this application they are also obsolete, having been replaced entirely by electric lamps, and in some cases, by LED lamps.

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