Oxford Cambridge and RSA

For issue on or after: 13 March 2023

A Level Chemistry B (Salters)

H433/02 Scientific literacy in chemistry

Advance Notice Article

To prepare candidates for the examination taken on Monday 19 June 2023 – Afternoon

INSTRUCTIONS

- Before the exam, read this article carefully and study the content of the learning outcomes for A Level Chemistry B (Salters).
- You can ask your teacher for advice and discuss this article with others in your class.
- You can investigate the topic of this article yourself using any resources available to you.
- Do **not** take this copy of the article or any notes into the exam.

INFORMATION

- In the exam you will answer questions on this article. The questions are worth 20–25 marks.
- A clean copy of this article will be given to you with the question paper.
- This document has **4** pages.

ADVICE

- In the exam you won't have time to read this article in full but you should refer to it in your answers.

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 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, $CaCN_2$. Calcium carbide is produced industrially in an electric-arc furnace from a mixture of $CaCO_3$ and coke (carbon) at approximately 2000 °C. This method has not changed since its invention in 1888:

$$CaCO_3 + 3C \rightarrow CaC_2 + CO + CO_2$$

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 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 l / kg. Impurities present in the carbide include phosphide, which produces PH_3 (a poisonous gas) when the CaC_2 is hydrolyzed to produce HC≡CH , i.e. acetylene.

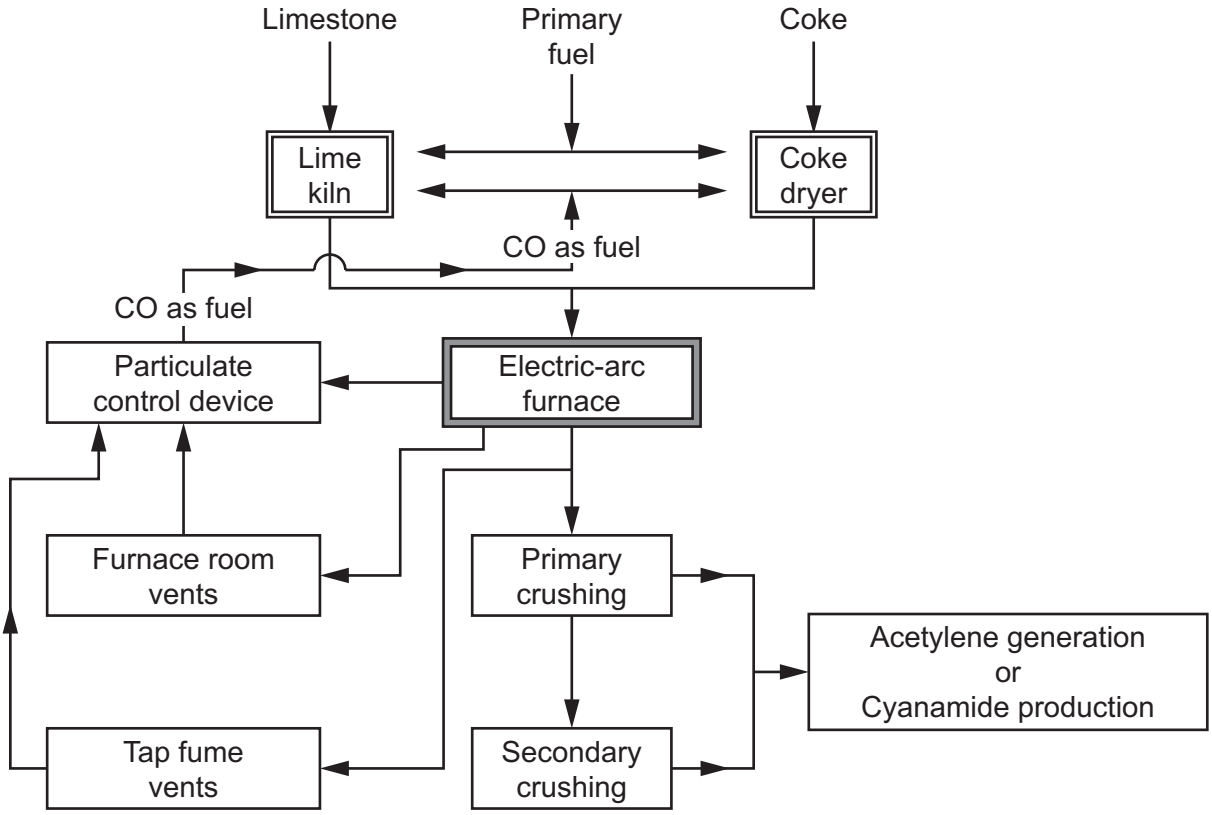
This reaction was an important part of the industrial revolution in chemistry, and was made possible in the U.S. as a product of massive amounts of cheap hydroelectric power generated at Niagara Falls before the turn of the twentieth century. The method for the production of CaC_2 in an electric-arc furnace was discovered independently by two researchers in Europe in 1888 and 1892. **Fig. 1** is an illustration of how CaC_2 has been manufactured.

The common crystalline form at room temperature is a distorted rock salt structure with the C_2^{2-} units lying parallel. In calcium carbide, CaC_2, the C≡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:

$$CaC_2 + 2H_2O \rightarrow HC{\equiv}CH + Ca(OH)_2$$

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:

$CaC_2 + N_2 \rightarrow CaCN_2 + C$

Calcium cyanamide is used as fertilizer. It is hydrolyzed to cyanamide, $H_2N–C{\equiv}N$, 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.

END OF ADVANCE NOTICE ARTICLE