



Carbon Compounds and Their Significance

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ABSTRACT: Carbon compounds are defined as chemical substances containing carbon.^{[1][2]} More compounds of carbon exist than any other chemical element except for hydrogen. Organic carbon compounds are far more numerous than inorganic carbon compounds. In general bonds of carbon with other elements are covalent bonds. Carbon is tetravalent but carbon free radicals and carbenes occur as short-lived intermediates. Ions of carbon are carbocations and carbanions are also short-lived. An important carbon property is catenation as the ability to form long carbon chains and rings.^[3]

KEYWORDS: carbon, chemical, organic, covalent, free radicals, catenations, rings, chains, tetravalent

I. INTRODUCTION

The known inorganic chemistry of the allotropes of carbon (diamond, graphite, and the fullerenes) blossomed with the discovery of buckminsterfullerene in 1985, as additional fullerenes and their various derivatives were discovered. One such class of derivatives is inclusion compounds, in which an ion is enclosed by the all-carbon shell of the fullerene. This inclusion is denoted by the "@" symbol in endohedral fullerenes. For example, an ion consisting of a lithium ion trapped within buckminsterfullerene would be denoted $\text{Li}^+@C_{60}$. As with any other ionic compound, this complex ion could in principle pair with a counterion to form a salt. Other elements are also incorporated in so-called graphite intercalation compounds.

Carbides are binary compounds of carbon with an element that is less electronegative than it. The most important are Al_4C_3 , B_4C , CaC_2 , Fe_3C , HfC , SiC , TaC , TiC , and WC .

Metal	Structure of pure metal	Metallic radius (pm)	MC metal atom packing	MC structure	M ₂ C metal atom packing	M ₂ C structure	Other carbides
titanium	hcp	147	ccp	rock salt			
zirconium	hcp	160	ccp	rock salt			
hafnium	hcp	159	ccp	rock salt			
vanadium	bcc	134	ccp	rock salt	hcp	h/2	V_4C_3
niobium	bcc	146	ccp	rock salt	hcp	h/2	Nb_4C_3
tantalum	bcc	146	ccp	rock salt	hcp	h/2	Ta_4C_3
chromium	bcc	128					Cr_{23}C_6 , Cr_3C , Cr_7C_3 , Cr_3C_2
molybdenum	bcc	139		hexagonal	hcp	h/2	Mo_3C_2
tungsten	bcc	139		hexagonal	hcp	h/2	

In chemistry, a carbide usually describes a compound composed of carbon and a metal. In metallurgy, carburizing or carbiding is the process for producing carbide coatings on a metal piece.^[1] The carbides of the group 4, 5 and 6 transition metals (with the exception of chromium) are often described as interstitial compounds.^[2] These carbides have metallic properties and are refractory. Some exhibit a range of stoichiometries, being a non-stoichiometric mixture of various carbides arising due to crystal defects. Some of them, including titanium carbide and tungsten carbide, are important industrially and are used to coat metals in cutting tools.^[3]



The long-held view is that the carbon atoms fit into octahedral interstices in a close-packed metal lattice when the metal atom radius is greater than approximately 135 pm:^[2]

- When the metal atoms are cubic close-packed, (ccp), then filling all of the octahedral interstices with carbon achieves 1:1 stoichiometry with the rock salt structure.^[4]
- When the metal atoms are hexagonal close-packed, (hcp), as the octahedral interstices lie directly opposite each other on either side of the layer of metal atoms, filling only one of these with carbon achieves 2:1 stoichiometry with the CdI₂ structure.^[4]

The following table^{[2][3]} shows structures of the metals and their carbides. (N.B. the body centered cubic structure adopted by vanadium, niobium, tantalum, chromium, molybdenum and tungsten is not a close-packed lattice.) The notation "h/2" refers to the M₂C type structure described above, which is only an approximate description of the actual structures. The simple view that the lattice of the pure metal "absorbs" carbon atoms can be seen to be untrue as the packing of the metal atom lattice in the carbides is different from the packing in the pure metal, although it is technically correct that the carbon atoms fit into the octahedral interstices of a close-packed metal lattice.

Carbides can be generally classified by the chemical bonds type as follows:

1. salt-like (ionic),
2. covalent compounds,
3. interstitial compounds, and
4. "intermediate" transition metal carbides.

Examples include calcium carbide (CaC₂), silicon carbide (SiC), tungsten carbide (WC; often called, simply, carbide when referring to machine tooling), and cementite (Fe₃C),^[2] each used in key industrial applications. The naming of ionic carbides is not systematic.

Salt-like / saline / ionic carbides

Salt-like carbides are composed of highly electropositive elements such as the alkali metals, alkaline earth metals, lanthanides, actinides, and group 3 metals (scandium, yttrium, and lutetium). Aluminium from group 13 forms carbides, but gallium, indium, and thallium do not. These materials feature isolated carbon centers, often described as "C⁴⁻", in the methanides or methides; two-atom units, "C₂-2", in the acetylides; and three-atom units, "C₄-3", in the allylides.^[2] The graphite intercalation compound KC₈, prepared from vapour of potassium and graphite, and the alkali metal derivatives of C₆₀ are not usually classified as carbides.^[8]

Methanides

Methanides are a subset of carbides distinguished by their tendency to decompose in water producing methane. Three examples are aluminium carbide Al₄C₃, magnesium carbide Mg₂C^[9] and beryllium carbide Be₂C.

Transition metal carbides are not saline: their reaction with water is very slow and is usually neglected. For example, depending on surface porosity, 5–30 atomic layers of titanium carbide are hydrolyzed, forming methane within 5 minutes at ambient conditions, following by saturation of the reaction.^[10]

Note that methanide in this context is a trivial historical name. According to the IUPAC systematic naming conventions, a compound such as NaCH₃ would be termed a "methanide", although this compound is often called methylsodium.^[11] See Methyl group#Methyl anion for more information about the CH₃⁻ anion.¹⁰

Acetylides/ethynides

Several carbides are assumed to be salts of the acetylide anion C₂-2 (also called percarbide, by analogy with peroxide), which has a triple bond between the two carbon atoms. Alkali metals, alkaline earth metals, and lanthanoid metals form acetylides, for example, sodium carbide Na₂C₂, calcium carbide CaC₂, and LaC₂.^[2] Lanthanides also form carbides (sesquicarbides, see below) with formula M₂C₃. Metals from group 11 also tend to form acetylides, such as copper(I) acetylide and silver acetylide. Carbides of the actinide elements, which have stoichiometry MC₂ and M₂C₃, are also described as salt-like derivatives of C₂-2.

The C–C triple bond length ranges from 119.2 pm in CaC₂ (similar to ethyne), to 130.3 pm in LaC₂ and 134 pm in UC₂. The bonding in LaC₂ has been described in terms of La^{III} with the extra electron delocalised into the antibonding orbital on C₂-2, explaining the metallic conduction.^[2]



Allylides

The polyatomic ion C_4^{-3} , sometimes called allylide, is found in Li_4C_3 and Mg_2C_3 . The ion is linear and is isoelectronic with CO_2 .^[2] The C–C distance in Mg_2C_3 is 133.2 pm.^[12] Mg_2C_3 yields methylacetylene, CH_3CCH , and propadiene, CH_2CCH_2 , on hydrolysis, which was the first indication that it contains C_4^{-3} .¹¹

Covalent carbides

The carbides of silicon and boron are described as "covalent carbides", although virtually all compounds of carbon exhibit some covalent character. Silicon carbide has two similar crystalline forms, which are both related to the diamond structure.^[2] Boron carbide, B_4C , on the other hand, has an unusual structure which includes icosahedral boron units linked by carbon atoms. In this respect boron carbide is similar to the boron rich borides. Both silicon carbide (also known as carborundum) and boron carbide are very hard materials and refractory. Both materials are important industrially. Boron also forms other covalent carbides, such as $B_{25}C$.¹²

II.DISCUSSION

It was once thought that organic compounds could only be created by living organisms. Over time, however, scientists learned how to synthesize organic compounds in the lab. The number of organic compounds is immense and the known number of defined compounds is close to 10 million.^[4] However, an indefinitely large number of such compounds is theoretically possible. By definition, an organic compound must contain at least one atom of carbon, but this criterion is not generally regarded as sufficient. Indeed, the distinction between organic and inorganic compounds is ultimately a matter of convention, and there are several compounds that have been classified either way, such as: $COCl_2$, $CSCl_2$, $CS(NH_2)_2$, $CO(NH_2)_2$. With carbon bonded to metals the field of organic chemistry crosses over into organometallic chemistry.¹³

There is a rich variety of carbon chemistry that does not fall within the realm of organic chemistry and is thus called inorganic carbon chemistry.

Carbon-oxygen compounds

There are many oxides of carbon (oxocarbons), of which the most common are carbon dioxide (CO_2) and carbon monoxide (CO). Other less known oxides include carbon suboxide (C_3O_2) and mellitic anhydride ($C_{12}O_9$).^[5] There are also numerous unstable or elusive oxides, such as dicarbon monoxide (C_2O), oxalic anhydride (C_2O_4), and carbon trioxide (CO_3).

There are several oxocarbon anions, negative ions that consist solely of oxygen and carbon. The most common are the carbonate (CO_3^{2-}) and oxalate ($C_2O_4^{2-}$). The corresponding acids are the highly unstable carbonic acid (H_2CO_3) and the quite stable oxalic acid ($H_2C_2O_4$), respectively. These anions can be partially deprotonated to give the bicarbonate (HCO_3^-)¹⁴ and hydrogenoxalate ($HC_2O_4^-$). Other more exotic carbon–oxygen anions exist, such as acetylenedicarboxylate ($O_2C-C\equiv C-CO_2^{2-}$), mellitate ($C_{12}O_9^{6-}$), squarate ($C_4O_4^{2-}$), and rhodizonate ($C_6O_6^{2-}$). The anhydrides of some of these acids are oxides of carbon; carbon dioxide, for instance, can be seen as the anhydride of carbonic acid.

Some important carbonates are Ag_2CO_3 , $BaCO_3$, $CaCO_3$, $CdCO_3$, $Ce_2(CO_3)_3$, $CoCO_3$, Cs_2CO_3 , $CuCO_3$, $FeCO_3$, K_2CO_3 , $La_2(CO_3)_3$, Li_2CO_3 , $MgCO_3$, $MnCO_3$, $(NH_4)_2CO_3$, Na_2CO_3 , $NiCO_3$, $PbCO_3$, $SrCO_3$, and $ZnCO_3$.

The most important bicarbonates include NH_4HCO_3 , $Ca(HCO_3)_2$, $KHCO_3$, and $NaHCO_3$.

The most important oxalates include $Ag_2C_2O_4$, BaC_2O_4 , CaC_2O_4 , $Ce_2(C_2O_4)_3$, $K_2C_2O_4$, and $Na_2C_2O_4$.

Carbonyls are coordination complexes between transition metals and carbonyl ligands. Metal carbonyls are complexes that are formed with the neutral ligand CO . These complexes are covalent. Here is a list of some carbonyls: $Cr(CO)_6$, $Co_2(CO)_8$, $Fe(CO)_5$, $Mn_2(CO)_{10}$, $Mo(CO)_6$, $Ni(CO)_4$, $W(CO)_6$.



III.RESULTS

Carbon-sulfur compounds

Important inorganic carbon-sulfur compounds are the carbon sulfides carbon disulfide (CS₂) and carbonyl sulfide (OCS). Carbon monosulfide (CS) unlike carbon monoxide is very unstable. Important compound classes are thiocarbonates, thiocarbamates, dithiocarbamates and trithiocarbonates.¹⁵

carbon monosulfide	carbon disulfide	carbonyl sulfide
Inorganic carbon-sulfur compounds		

Carbon-nitrogen compounds

Small inorganic carbon – nitrogen compounds are cyanogen, hydrogen cyanide, cyanamide, isocyanic acid and cyanogen chloride.

	composition		Molar mass (g/mole)	Boiling point °C	Melting point °C
cyanogen	(CN) ₂	$N \equiv C - C \equiv N$	52.03	-21	-28
hydrogen cyanide	HCN	$H - C \equiv N$	27.03	25-26	-12 - -14
cyanamide	CN ₂ H ₂		42.04	260 (decomp.)	44
isocyanic acid	HNCO	$H - N = C = O$	43.03	23.5	-86
cyanogen chloride	CNCl	$N \equiv C - Cl$	61.47	13	-6
chlorosulfonyl isocyanate	CNClO ₃ S		141.53	107	-44
cyanuric chloride	(NCCl) ₃		184.41	192	154

Inorganic carbon-nitrogen compounds

Paracyanogen is the polymerization product of cyanogen. Cyanuric chloride is the trimer of cyanogen chloride and 2-cyanoguanidine is the dimer of cyanamide.



Other types of inorganic compounds include the inorganic salts and complexes of the carbon-containing cyanide, cyanate, fulminate, thiocyanate and cyanamide ions. Examples of cyanides are copper cyanide (CuCN) and potassium cyanide (KCN), examples of cyanates are potassium cyanate (KNCO) and silver cyanate (AgNCO), examples of fulminates are silver fulminate (AgOCN) and mercury fulminate (HgOCN) and an example of a thiocyanate is potassium thiocyanate (KSCN).

IV. CONCLUSIONS

The common carbon halides are carbon tetrafluoride (CF₄), carbon tetrachloride (CCl₄), carbon tetrabromide (CBr₄), carbon tetraiodide (CI₄), and a large number of other carbon-halogen compounds. A carborane is a cluster composed of boron and carbon atoms such as H₂C₂B₁₀H₁₀.... There are hundreds of alloys that contain carbon. The most common of these alloys is steel, sometimes called "carbon steel" (see Category:Steels). All kinds of steel contain some amount of carbon, by definition, and all ferrous alloys contain some carbon.

Some other common alloys that are based on iron and carbon include anthracite iron, cast iron, pig iron, and wrought iron.

In more technical uses, there are also spiegeleisen, an alloy of iron, manganese, and carbon; and stellite, an alloy of cobalt, chromium, tungsten, and carbon.

Whether it was placed there deliberately or not, some traces of carbon is also found in these common metals and their alloys: aluminum, chromium, magnesium, molybdenum, niobium, thorium, titanium, tungsten, uranium, vanadium, zinc, and zirconium. For example, many of these metals are smelted with coke, a form of carbon; and aluminum and magnesium are made in electrolytic cells with carbon electrodes. Some distribution of carbon into all of these metals is inevitable.¹⁶

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