

## Table of Contents

<b>Introduction</b> . . . . .	xi
<b>Chemical Glossary</b> . . . . .	xvii
<b>Chapter 1. From the Chemical Element to Solids.</b> . . . . .	1
1.1. Carbon on Earth. . . . .	1
1.2. A brief history of the chemistry of carbon . . . . .	5
1.2.1. The first discoveries: fire, heat and metals. . . . .	9
1.2.2. Exploitation of mined resources . . . . .	11
1.2.3. Uses of dispersed carbons . . . . .	13
1.3. Presentation of carbon solids. . . . .	14
1.3.1. Comparison of natural and artificial evolution . . . . .	16
1.3.2. Production and development of carbonaceous products . . . . .	17
1.4. Conclusion and perspectives. . . . .	18
1.5. Bibliography . . . . .	19
<b>Chapter 2. The Polymorphism of Carbon.</b> . . . . .	23
2.1. The carbon atom and its chemical bonds . . . . .	24
2.1.1. Chemical bonds and solid phases . . . . .	24
2.1.2. Carbon isotopes . . . . .	26
2.2. A thermodynamic approach . . . . .	27
2.2.1. Some reminders about phenomenological thermodynamics . . . . .	27

2.2.2. Diagram of equilibrium states of carbon . . . . .	28
2.3. New molecular phases . . . . .	30
2.4. Non-crystalline carbons . . . . .	32
2.4.1. Principal processes . . . . .	33
2.4.2. Evolution and structural characterizations . . . . .	35
2.4.3. Homogeneous massive carbons . . . . .	40
2.4.4. Porous and dispersed carbons . . . . .	42
2.5. From solids to materials . . . . .	44
2.6. Bibliography . . . . .	45

### **Chapter 3. Natural Carbons: Energy Source and Carbochemistry . . . . . 47**

3.1. Primary energy sources . . . . .	48
3.1.1. The various forms of energy . . . . .	48
3.1.2. Combustion of natural coals . . . . .	53
3.1.3. Manufacturing cements . . . . .	57
3.1.4. Gasification and liquefaction procedures . . . . .	57
3.2. Carbochemistry . . . . .	58
3.2.1. Intermediary products: coal tar and pitch . . . . .	60
3.2.2. Solid primary materials: cokes and artificial graphites . . . . .	63
3.3. Use of coal resources . . . . .	64
3.3.1. Primary energy source . . . . .	64
3.3.2. The future of carbochemistry and carbonaceous materials . . . . .	67
3.4. Summation and essential points . . . . .	68
3.5. Bibliography . . . . .	68

### **Chapter 4. The Role of Carbon in Metallurgy . . . . . 71**

4.1. Principles and evolution of the steel industry . . . . .	72
4.1.1. Industrial manufacturing for cast iron and steel . . . . .	75
4.1.2. Carbons in the steel industry . . . . .	77
4.2. The manufacturing of aluminum . . . . .	78
4.2.1. Electrolysis tank . . . . .	78
4.2.2. Carbons for the aluminum industry . . . . .	79
4.3. Silicon production . . . . .	80
4.3.1. Obtaining metallurgical silicon . . . . .	80

4.3.2. Carbon electrodes . . . . .	81
4.4. Metallic carbides . . . . .	81
4.4.1. Synthesis of acetylene . . . . .	82
4.4.2. Refractory carbides . . . . .	82
4.5. Summary and essential points . . . . .	83
4.6. Bibliography . . . . .	84
<b>Chapter 5. Black and White Ceramics . . . . .</b>	<b>85</b>
5.1. Graphites and isotropic carbons . . . . .	86
5.1.1. Manufacturing artificial graphites . . . . .	86
5.1.2. General physical properties . . . . .	88
5.1.3. Glassy carbons . . . . .	91
5.1.4. Major areas of application . . . . .	92
5.2. Pyrocarbons and pyrographites . . . . .	94
5.2.1. Pyrocarbons (Pyc) obtained via vapor-phase chemical deposit . . . . .	95
5.2.2. Textural and physical characteristics . . . . .	96
5.2.3. Pyrographites and analogs . . . . .	99
5.3. Films of diamond . . . . .	100
5.3.1. Thin layer processes. . . . .	100
5.3.2. Properties and fields of application . . . . .	102
5.4. Summary and essential points . . . . .	103
5.5. Bibliography . . . . .	104
<b>Chapter 6. Dispersed and Porous Carbons . . . . .</b>	<b>107</b>
6.1. Carbon blacks . . . . .	108
6.1.1. Formation mechanisms and industrial processes . . . . .	108
6.1.2. Classification and characteristics. . . . .	110
6.1.3. Other carbon particles . . . . .	112
6.2. Shaping and fields of application . . . . .	113
6.2.1. Reminder on heterogeneous media . . . . .	113
6.2.2. Main domains of exploitation. . . . .	116
6.3. Porous and adsorbent carbons . . . . .	119
6.3.1. General definitions . . . . .	119
6.3.2. Activated carbons . . . . .	123
6.3.3. Purification and transport in the gaseous phase. . . . .	125
6.3.4. Uses in the liquid phase . . . . .	126

6.4. Summary and essential points. . . . .	128
6.5. Bibliography . . . . .	129
<b>Chapter 7. Fibers and Composites . . . . .</b>	<b>131</b>
7.1. Carbon filaments . . . . .	132
7.1.1. Historic overview of the main families . . . . .	132
7.1.2. Textural characteristics and physical properties . . . . .	136
7.2. Composite materials. . . . .	139
7.2.1. Fiber-matrix interface . . . . .	139
7.2.2. Main categories of composites and nanocomposites . . . . .	143
7.2.3. Manufacture of carbon-carbon composites . . . . .	145
7.2.4. Applications of carbon-carbon composites . . . . .	148
7.3. Summary and essential points. . . . .	151
7.4. Bibliography . . . . .	152
<b>Chapter 8. Molecular Carbons and Nanocarbons . . . . .</b>	<b>155</b>
8.1. Synthesis and production. . . . .	156
8.1.1. Synthesis and characterization of fullerenes . . . . .	156
8.1.2. Formation and identification of nanotubes . . . . .	157
8.1.3. Manufacture and stabilization of graphene ribbons. . . . .	160
8.2. Transport and nanoelectronic properties . . . . .	162
8.2.1. Electronic transport in single-wall nanotubes and graphene ribbons. . . . .	165
8.2.2. Molecular transistors and logic circuits . . . . .	166
8.2.3. Associated quantum phenomena . . . . .	168
8.3. Physical chemistry of interface and sensors . . . . .	169
8.3.1. Chemical functionalization of surfaces . . . . .	170
8.3.2. Sensors, biosensors and actuators . . . . .	173
8.3.3. Comments on biological compatibility. . . . .	175
8.4. Conclusion and prospective . . . . .	176
8.5. Bibliography . . . . .	176
<b>Chapter 9. Carbon Techniques and Innovation . . . . .</b>	<b>179</b>
9.1. Evolution of carbon materials. . . . .	180
9.1.1. Different generations of carbonaceous materials . . . . .	180

9.1.2. Classification by purpose and areas of activity . . . . .	182
9.1.3. Role in energy problems . . . . .	183
9.2. Socio-economic aspects . . . . .	186
9.2.1. Economic assessments . . . . .	186
9.2.2. Economic transitions and cycles . . . . .	188
9.3. Epilogue . . . . .	191
9.4. Bibliography . . . . .	192
<b>Index . . . . .</b>	<b>195</b>