

## CHAPTER

<b>1. Introduction</b>	<b>1</b>
1.1. Synthetic Fuels and Their Manufacture	1
1.2. History	6
1.3. Properties of Coal, Oil shale, and tar Sands	11
1.4. Resources	21
<b>2. Chemical and Physical Fundamentals</b>	<b>31</b>
2.1. Chemistry for Synthetic Fuels	31
2.2. Thermodynamics for synthetic Fuels	48
2.3. Reaction Kinetics and Catalysis	72
2.4. Reactor considerations	83
<b>3. Conversion fundamentals</b>	<b>95</b>
3.1. Pyrolysis	95
3.2. Gasification	111
3.3. Gas shift and synthesis	123
3.4. Direct liquefaction	131
3.5. Comparison of synthetic Fuel Routes	138
<b>4. Gasi from Coal</b>	<b>144</b>
4.1. Gasification Technologies	144
4.2. Steam/Oxygen and Steam/Air gasification	156
4.3. Indirectly Heated and Molten Media Gasification	182
4.4. Hydrogasification and catalytic gasification	189
4.5. Underground Gasification	202
<b>5. Gas Upgrading</b>	<b>210</b>
5.1. Gas Cleaning and Purification	210
5.2. Shift and Methanation	221
5.3. Oxygen production	226
5.4. Hydrogen production	233
5.5. Integrated plants	238
<b>6. Liquids and clean Solids from coal</b>	<b>257</b>
6.1. Liquefaction and coal refining Technologies	257
6.2. Indirect Liquefaction	264
6.3. Pyrolysis	280
6.4. Direct liquefaction	291
6.5. Upgrading coal liquids	309
<b>7. Liquids from Oil shale and Tar sands</b>	<b>322</b>

7.1 Oil shale Retorting	322
7.2. Integated oil shale plants	346
7.3. Tar sands recovery	359
7.4. Integrated tar sands plants	371
<b>8. Biomass Conversion</b>	<b>381</b>
8.1. Resources	381
8.2. Biochemical Conversion	390
8.3. Thermal conversion	401
<b>9. Environmental Aspects</b>	<b>411</b>
9.1. Environmental Effects and their measure	411
9.2. Air Pollution Control	420
9.3. Waste Management	430
9.4. Solid Wastes Disposal	437
<b>10. Economics and Perspective</b>	<b>442</b>
10.1. Economic considerations	442
10.2. Resource, process, and product considerations	448
<b>Appendixes</b>	<b>456</b>
<b>A. Constants and Conversion Factors</b>	<b>458</b>
<b>B. Symbols and Acronyms</b>	<b>463</b>