

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Is Entropy Really Necessary?	3
1.2	A Didactic Model for the Logical Structure of the Entropy Principle	4
<b>2</b>	<b>Adiabatic Accessibility</b>	<b>9</b>
2.1	Thermodynamic Systems	11
2.2	Equilibrium States	11
2.3	The Order Relation $\prec$	12
2.4	A First Glance at Entropy	16
2.5	Coordinates	20
2.6	Properties of Adiabatic Accessibility	24
	A – Comparability	25
	B – Transitivity	30
	C – Consistency	30
	D – Stability	32
	E – Condition of Convex Combination	33
<b>3</b>	<b>Entropy</b>	<b>35</b>
3.1	Entropy of Water	37
3.2	Entropy of Further Substances	43
3.3	Mixing and Chemical Reactions	47
3.4	The Entropy Principle	48
3.5	Properties of Entropy	49
	A – Monotonicity	49
	B – Additivity	50
	C – Concavity	52
<b>4</b>	<b>General Conclusions</b>	<b>53</b>
4.1	Irreversible and Reversible Processes	55
4.2	Thermal Equilibrium and Temperature	58
4.3	Heat and Heat Flux	61
	A – Beware of Heat!	61
	B – Definition of “Heat” for Arbitrary Processes	62
	C – Definition of “Heat” for Quasistatic Processes	63
	D – Heat Transfer	65

4.4	The Second Law of Thermodynamics .....	66
	A – The Clausius Formulation of the Second Law .....	67
	B – The Kelvin-Planck Formulation of the Second Law .....	68
	C – The Carathéodory Formulation of the Second Law .....	69
4.5	Efficiency of Heat Engines and Refrigeration Cycles .....	70
	A – Efficiency of a Heat Engine .....	70
	B – Coefficient of Performance of a Refrigeration System .....	73
	C – Coefficient of Performance of a Heat Pump .....	75
4.6	Fundamental Thermodynamic Functions .....	76
	A – Internal Energy .....	77
	B – Enthalpy .....	80
	C – Helmholtz Function .....	82
	D – Gibbs Function .....	83
4.7	Determination of the Entropy of Simple Systems .....	85
<b>5</b>	<b>Specific Applications .....</b>	<b>87</b>
5.1	Generation of Energy from the Gulf Stream .....	89
	A – Formulation of the Problem .....	90
	B – Entropy of an Incompressible Substance .....	91
	C – Result and Discussion .....	93
	D – Suggestions for Further Study .....	95
5.2	Air Conditioning .....	96
	A – Formulation of the Problem .....	96
	B – Entropy of an Ideal Gas .....	98
	C – Result and Discussion .....	99
	D – Suggestions for Further Study .....	101
5.3	Ice Skating .....	103
	A – Formulation of the Problem .....	103
	B – Entropy of a Two-Phase System .....	104
	C – Result and Discussion .....	106
	D – Suggestions for Further Study .....	108
5.4	Analysis of a Vapor Power System .....	110
	A – Formulation of the Problem .....	110
	B – Entropy of Ammonia .....	112
	C – Result and Discussion .....	113
	D – Suggestions for Further Study .....	116
5.5	Analysis of a Refrigeration System .....	118
	A – Formulation of the Problem .....	119
	B – Entropy of the Refrigerant R-134a .....	119
	C – Result and Discussion .....	120
	D – Suggestions for Further Study .....	123
5.6	Production of Ammonia .....	124
	A – Formulation of the Problem .....	124
	B – Entropy and Gibbs Function of a Mixture of Ideal Gases .....	128
	C – Result and Discussion .....	131
	D – Suggestions for Further Study .....	133

5.7	Production of Distilled Beverages .....	136
	A – Formulation of the Problem .....	136
	B – Entropy and Gibbs Function of a Dilute Mixture of Two Ideal Gases ...	138
	C – Entropy and Gibbs Function of a Dilute Ideal Solution .....	139
	D – Entropy and Gibbs Function of a Boiling Dilute Ideal Solution .....	141
	E – Result and Discussion .....	142
	F – Suggestions for Further Study .....	144
6	Summary .....	147
	References and Further Reading .....	151
	References .....	153
	Suggestions for Further Reading .....	153
	Appendices .....	155
	Appendix A: Hans in Luck .....	157
	Appendix B: Axioms for the Derivation of the Entropy Principle .....	161
	Appendix C: Irreversible and Reversible Heat Transfer .....	164
	Appendix D: Properties of the Mixing Entropy .....	166
	Appendix E: Entropy and Gibbs Function of a Dilute Mixture of Ideal Gases and of a Dilute Ideal Solution .....	167
	Appendix F: Auxiliary Expressions for the Analysis of the Production of Distilled Beverages .....	169
	Appendix G: Explanation of the Examples of Entropy Production in Everyday Live .....	171
	Index .....	175