

Contents

1	Energy Release in Nuclear Reactions, Neutrons, Fission, and Characteristics of Fission	1
1.1	Notational Conventions for Mass Excess and Q -Values	2
1.2	Rutherford and the Energy Release in Radium Decay	3
1.3	Rutherford's First Artificial Nuclear Transmutation	5
1.4	Discovery of the Neutron	6
1.5	Artificially-Induced Radioactivity and the Path to Fission	14
1.6	Energy Release in Fission	19
1.7	The Bohr–Wheeler Theory of Fission: The Z^2/A Limit Against Spontaneous Fission	20
1.8	Energy Spectrum of Fission Neutrons	25
1.9	Leaping the Fission Barrier	27
1.10	A Semi-Empirical Look at the Fission Barrier	32
	References	36
2	Critical Mass and Efficiency	39
2.1	Neutron Mean Free Path	40
2.2	Critical Mass: Diffusion Theory	45
2.3	Effect of Tamper	51
2.4	Estimating Bomb Efficiency: Analytic	58
2.5	Estimating Bomb Efficiency: Numerical	66
2.5.1	A Simulation of the Hiroshima Little Boy Bomb	69
2.6	Another Look at Untamped Criticality: Just One Number	72
	References	74
3	Producing Fissile Material	75
3.1	Reactor Criticality	75
3.2	Neutron Thermalization	78
3.3	Plutonium Production	81
3.4	Electromagnetic Separation of Isotopes	84

3.5 Gaseous (Barrier) Diffusion	90
References	95
4 Complicating Factors	97
4.1 Boron Contamination in Graphite	98
4.2 Spontaneous Fission of ^{240}Pu , Predetonation, and Implosion	100
4.2.1 Little Boy Predetonation Probability	105
4.2.2 Fat Man Predetonation Probability	105
4.3 Tolerable Limits for Light-Element Impurities	108
References	112
5 Miscellaneous Calculations	115
5.1 How Warm is It?	115
5.2 Brightness of the <i>Trinity</i> Explosion	116
5.3 Model for Trace Isotope Production in a Reactor	120
References	125
6 Appendices	127
6.1 Appendix A: Selected Δ -Values and Fission Barriers	127
6.2 Appendix B: Densities, Cross-Sections and Secondary Neutron Numbers	128
6.2.1 Thermal Neutrons (0.0253 eV)	128
6.2.2 Fast Neutrons (2 MeV)	128
6.3 Appendix C: Energy and Momentum Conservation in a Two-Body Collision	129
6.4 Appendix D: Energy and Momentum Conservation in a Two-Body Collision that Produces a Gamma-Ray	132
6.5 Appendix E: Formal Derivation of the Bohr–Wheeler Spontaneous Fission Limit	134
6.5.1 E1: Introduction	134
6.5.2 E2: Nuclear Surface Profile and Volume	135
6.5.3 E3: The Area Integral	138
6.5.4 E4: The Coulomb Integral and the SF Limit	139
6.5.5 References	144
6.6 Appendix F: Average Neutron Escape Probability from Within a Sphere	144
6.7 Appendix G: The Neutron Diffusion Equation	146
6.7.1 References	154
6.8 Appendix H: Questions	154
6.9 Answers	161
6.10 Appendix I: Further Reading	162
6.10.1 General Works	163
6.10.2 Biographical and Autobiographical Works	164

Contents	xiii
6.10.3 Technical Works	166
6.10.4 Websites	167
6.11 Appendix J: Useful Constants and Conversion Factors	168
6.11.1 Rest Masses	168
Index	169