

# The Science of the Cold Fusion Phenomenon

## 2<sup>nd</sup> Edition

### Table of Contents

The Sections newly inserted in this Revised 2<sup>nd</sup> Edition are asterisked as “1.5.5\* DOE Report 2004.”

#### **Preface to the second edition\***

Preface to the first edition

#### **1 Discovery of the Cold Fusion Phenomenon (CFP)**

##### **1.1 The First Experiments**

##### **1.2 The Experiment by Fleischmann et al.**

1.2.1 The Problem of Reproducibility

1.2.2\* Control Experiments with Light Water

##### **1.3 Confirmation of the Experiment by Fleischmann et al.**

1.3.1 Free Space

1.3.2 Conditions for Fusion Reactions in Solids

1.3.3 Results of Nuclear Reactions (1.3-1) – (1.3-3)

1.3.4 Comparison of Generated Energy with Energies of Other Relevant Particles

##### **1.4\* Experiments by Jones et al. and De Ninno et al.**

1.4.1\* Experiment by Jones et al.

1.4.2\* Experiment by De Ninno et al.

##### **1.5 Scandals**

1.5.1\* G. Taubes reports Situation around the Discovery

1.5.2\* DOE Report 1989 and the Book by J.R. Huizenga

1.5.3 Shortcomings of DOE Report 1989 imposed by the Propositions of Researchers

1.5.4 The Dawn of a Science – New Perspectives needed by New Experimental Facts

1.5.5\* DOE Report 2004

##### **1.6 Experiments with Light Water H<sub>2</sub>O**

##### **1.7 Facts and Truth**

##### **1.8\* DOE Report 2004 – Evaluation of Proposed Explanation of the CFP**

##### **1.9\* Chemistry, Physics and Mathematics**

1.9.1 Electrochemistry and Nuclear Chemistry

1.9.2 Solid-State Physics and Nuclear Physics

1.9.3 Mathematics of the CFP – Nonlinear Dynamics

## **2 Facts of the Cold Fusion Phenomenon (CFP)**

### **2.1 How the Experiments are conducted?**

### **2.2\* Where and How the Cold Fusion Phenomenon occurs?**

#### 2.2.1\* The Cold Fusion Phenomenon in Transition-Metal Hydrides and Deuterides

##### 2.2.1.1 Review of experimental data sets

##### 2.2.1.2 Difference of hydrated and deuterated alloys

##### 2.2.1.3 Importance of surface and boundary layers in CFP

##### 2.2.1.4 Use of multilayered CF materials

##### 2.2.1.5 Nuclear Transmutation in Critical and Supra-critical Electrolysis with W, Re, Pt and Au Cathodes

##### 2.2.1.6 Role of background neutrons

#### 2.2.2\* Cold Fusion Phenomenon in Hydrogen-Carbon Systems (cf. Sec. 2.5.6)

#### 2.2.3\* CFP in Systems with Complex Structures 160417

### **2.3 Number of Reactions $N_x$ producing an Observable $x$**

### **2.4 Outline of TNCF Model and Neutron Drop Model – Basis of Data Analysis**

#### 2.4.1 TNCF (Trapped Neutron Catalyzed Fusion) Model (cf. Sec. 3.2)

#### 2.4.2 Neutron Drop Model – Extension of the TNCF model (cf. Sec. 3.6)

### **2.5 Nuclear Transmutations (NT's)**

#### 2.5.1 Nuclear Transmutation by Decay $NT_D$

#### 2.5.2 Nuclear Transmutation by Absorption $NT_A$

#### 2.5.3 Nuclear Transmutation by Fission $NT_F$

#### 2.5.4 Nuclear Transmutation by Transformation $NT_T$

#### 2.5.5 Isotopic Ratios of Generated Nuclides by NT's

#### 2.5.6\* NT's in Critical and Supra-critical Electrolysis – 5d Transition Metals

#### 2.5.7\* NT's in Carbon-Hydrogen Systems – Hydrogen-Graphite, Cross-linked Polyethylene (XLPE) and Biological Systems

##### 2.5.7.1\* Hydrogen Graphite – Nuclear Transmutation in Carbon Arc Systems

##### 2.5.7.2\* Nuclear Transmutations in Cross-linked Polyethylene (XLPE)

##### 2.5.7.3\* Biological Systems – Biotransmutation in Bacterial Cultures

#### 2.5.8\* NT's in multilayered CF materials

#### 2.5.9\* Decay Time Shortening of Radioactive Nuclides

### **2.6 Tritium T (or triton ${}^3_1\text{H} = t$ )**

### **2.7 Neutron $n$**

#### 2.7.1 Effect of Thermal Neutrons on the Neutron Emission

### **2.8 Helium-3 ( ${}^3_2\text{He}$ ) and Helium-4 ( ${}^4_2\text{He}$ )**

### **2.9 Excess Heat $Q$**

2.9.1 Excess Heat in general

2.9.2 Extensive Measurement of Excess Heat by McKubre et al.

### **2.10\* Emission of Charged Particles and CR39 Detector**

2.10.1\* Emission of Charged Particles in CFP

2.10.2\* Characteristics of CR39 Particle Detector

### **2.11\* Localization of the Cold Fusion Phenomenon**

### **2.12 Absence of Gamma Ray ( $\gamma$ )**

### **2.13\* Three Empirical Laws in the CFP\***

2.13.1\* The Stability Effect in Nuclear Transmutation

2.13.2\* The Inverse-power Law for Occurrence of Events in the CFP

2.13.3\* Complexity of the CFP – Bifurcation and Chaotic Behavior

2.13.4\* Physical Meaning of the Three Laws in the CFP

2.13.5\* Nonlinear Dynamics and Complexity

### **2.14 After Effect and Aging Effect**

2.14.1 After Effect

2.14.2 Aging Effect

### **2.15 The Qualitative Reproducibility**

### **2.16\* Temporal Evolution of the Cold Fusion Phenomenon – Positive Feedback and Explosion**

### **2.17 Summary of Experimental Results of the Cold Fusion Phenomenon**

2.17.1\* Summary of Experimental Results

2.17.2 Tables of Analyzed Data Sets given in the Previous Book

## **3 Science of the Cold Fusion Phenomenon**

### **3.1 Potency of a Model – Examples in Modern Physics**

3.1.1 Usefulness of Models in Science

### **3.2 The TNCF Model – A Phenomenological Approach**

3.2.1 Premises of the TNCF Model

3.2.2 Nuclear Reactions Relevant to the TNCF Model

3.2.3 Number of reactions relevant to the TNC model

3.2.4\* Extension of the TNCF Model – CF Matter and Neutron Drops (cf. Section 3.7)

### **3.3 Explanation of the Cold Fusion Phenomenon by the TNCF Model**

3.3.1 Relations between Observed Values of Physical Quantities

3.3.2 Absolute Value of Adjustable Parameter  $n_n$

3.3.3\* Temporal Evolution through the parameter  $n_n(\tau)$

3.3.4 Nuclear Transmutation Related to the Stability Effect

- 3.3.5 Generation of Helium-4 and Excess Heat
- 3.3.6 Explanation of Experimental Data Sets where Measured Several Observables
- 3.3.7 Neutron Energy Spectrum
- 3.3.8 Other Theoretical Trials to Explain Events in the CFP

### **3.4 Nuclear Reactions in Free Space and in Solids**

- 3.4.1 Nuclear Reactions in Free Space
- 3.4.2 Effects of Free Electrons in Metals
- 3.4.3 Effects of Lattice Oscillation
- 3.4.4 Effects of Electromagnetic Fields in Solids
- 3.4.5 Effects of Ion Beam and High-Voltage Discharge
- 3.4.6 Trials to Verify Fleischmann's Hypothesis

### **3.5 Quantum States of Neutrons and Properties of Lattice Nuclei**

- 3.5.1 Neutrons in Free Space
- 3.5.2\* Neutrons in Solid
- 3.5.3 Neutrons in a Nucleus
- 3.5.4\* Exotic Nuclei with Large Number of Excess Neutrons
- 3.5.5 Energetics of Lattice Nuclei related to the CFP

### **3.6 Hydrogen Isotopes in Transition Metals**

- 3.6.1 Hydrogen Isotopes in *fcc*, *hcp* and *bcc* Transition Metals
- 3.6.2 Excited States of a Proton (Deuteron) in CF Materials (*fcc* and *hcp* Transition-Metal Hydrides (Deuterides))

### **3.7 The CF-Matter and Neutron Drop Model**

- 3.7.1 Neutron – Proton Interaction in Solids
- 3.7.2 Super-Nuclear Interaction between Neutrons in Different Lattice Nuclei and Neutron Valence Band
- 3.7.3 Formation of CF-Matter including Neutron Drops
- 3.7.4 Energetics of Neutron Drop
- 3.7.5 The CF-Matter— Neutron Drops in Thin Neutron Gas Formed in Solids
- 3.7.6 The Neutron Drop Model of the CFP
- 3.7.7 Experimental Data Explained by the Neutron Drop Model
- 3.7.8\* Neutron Affinity and the CFP

### **3.8 The Cold Fusion Phenomenon as a Science of Complexity revealed by the Three Laws - Stability Effect, Inverse Power Law and Bifurcation –**

- 3.8.1\* Complexity Ubiquitous in the World
- 3.8.2 Conditions for CF-Matter Formation
- 3.8.3 Conditions for CF-Matter Destruction

3.8.4 Problem of the Reproducibility

3.8.5\* Applicability of the CFP

### **3.9\* Inductive Logic and the Meta-analysis in the Cold Fusion Phenomenon**

3.9.1 Inductive and Deductive Logic in Modern Science

3.9.2 Meta-analysis for Complex Data Sets

### **3.10 Conclusion**

3.10.1 Necessary conditions for the CFP

3.10.2\* Sociology of the cold fusion phenomenon

Epilogue to the First Edition

## **Epilogue to the Second Edition\***

## **Terminology\***

## **Appendices**

### **Appendix A. Usage of Symbols and Units in this Book**

A1. Symbols of Elements, Nuclides, and Radiation

A2. Units of Energy

A3. Units of Length

### **Appendix B. On the Conceptual Discrimination among Theory, Model and Hypothesis**

### **Appendix C. Typical Examples of Data Analysis on the TNCF Model**

C1. Analysis of Experimental Data Sets by Cellucci et al.

C2. Analysis of Experimental Data Sets by Chien et al.

C3. Analysis of Experimental Data Sets by Miles et al.

C4. Analysis of Experimental Data Sets by Clarke et al.

C5. Analysis of Experimental Data Sets by Okamoto et al.

C6. Analysis of Experimental Data Sets by Miley et al.

C7. Analysis of Experimental Data Sets by Dash et al.

C8. Analysis of Experimental Data Sets by Bressani et al.

C9\*. Analysis of Experimental Data Sets on XLPE by Kumazawa et al.

C10\*. Analysis of Experimental Data Sets on Pd Complexes by Iwamura et al.

C11\*. Analysis of Experimental Data Sets on Critical and Supra-critical Electrolysis by Ohmori et al.

C12.\* Analysis of Experimental Data Sets on the Biotransmutation by Vysotskii et al.

### **Appendix D. Topics from History of Science**

- Topic 1, Electromagnetic Wave, X ray, Gamma Ray
- Topic 2, Radioactivity – Unexpected Things Often Happen –
- Topic 3, Radium and Patent
- Topic 4, Quantum born as a Result of a Trial-and-Error
- Topic 5, Bohr’s Model of the Hydrogen Atom
- Topic 5a\*, Impact of the Bohr’s model to contemporaries
- Topic 6, Imagination discovered the Neutron
- Topic 7, Wonders of Transition-Metal Hydrides
- Topic 8, Background Neutron
- Topic 9,  $1/f$  Fluctuation
- Topic 10, Chaos, Fractal and Complexity

## **References\***

### **Indices**

Indices (1. Figures, 2. Tables)

Author index,

Subject index