Cold Fusion

History, the State of the Art, and an Experimental Cookbook

(with all the details for anyone who wants to "cook it up" in the lab)

Manuele Turini

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Abstract

"Cold fusion," or, more cautiously, low-energy nuclear reactions (LENR), refers to a set of phenomena observed in electrolytic cells containing palladium and heavy water that some researchers attribute to unconventional nuclear processes. More than thirty-five years after Fleischmann and Pons made their announcement in 1989, the phenomenon has yet to be reproduced reliably in a way that has gained universal acceptance. This document is written for curious general readers. After tracing the history and science, it presents an experimental "cookbook" with ingredients, voltages, electrolytes, measurement systems, and practical details drawn from the literature. No recipe can guarantee a result.

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1 Introduction

“Cold fusion” is one of those subjects that continues to divide the scientific community decades later. A vast and often uneven body of experimental literature reports excess heat, traces of helium-4, transmutations, and other anomalous signals. Established physics offers no mechanism by which two deuterium nuclei at room temperature could get close enough to overcome the Coulomb barrier. A series of failed replication attempts has fueled skepticism.

This document aims to remain neutral. It offers a candid overview of the state of the art and describes in as much detail as possible how the original experiment was conducted and what conditions researchers have identified as necessary when attempting to observe the effect. The second part is a “cookbook” for general readers, intended as an exercise in the history of science and experimental methodology. The procedure it describes remains unvalidated.

2 A Brief History

On 23 March 1989, Martin Fleischmann (University of Southampton) and Stanley Pons (University of Utah) announced at a press conference that they had observed excess heat in an electrolytic cell with a palladium cathode immersed in heavy water. The two electrochemists argued that conventional chemical reactions could not account for the energy produced and that the results pointed to a nuclear process.

The announcement came at a press conference before peer-reviewed publication and prompted intense media interest and a wave of replication attempts. Within a few months, most laboratories had failed to reproduce the thermal effect. The very few that reported positive results did so with disputed margins of error. The mainstream scientific community quickly attributed the findings to experimental error, particularly to underestimates of energy dissipation and electrolyte evaporation.

In the years that followed, the field survived on the margins of academia, with regular conferences (ICCF), dedicated journals, and a small but persistent group of researchers. In 2015, Google funded a multiyear project of controlled replication attempts. The project substantially improved the quality of the measurements and yielded no definitive evidence for the phenomenon. The debate remains open and there is no consensus.

3 What the Science Says Today

According to established physics, the fusion of two deuterons at room temperature would require overcoming a Coulomb barrier on the order of MeV, with an extremely low probability of tunneling. Any LENR hypothesis therefore requires new mechanisms, such as electron screening in the palladium lattice, chain reactions in microcavities, or low-energy transmutations. None of these hypotheses is universally accepted today.

Three issues stand out in the experimental work.

- **Reproducibility.** The vast majority of attempts produce no significant excess heat.
- **Calorimetry.** Many positive reports have turned out to reflect measurement errors caused by evaporation, thermal gradients, or inadequate calibration.
- **Nuclear by-products.** The traces of helium-4, tritium, or other isotopes reported in the literature have never been observed consistently and reproducibly with anomalous isotopic ratios and in quantities consistent with the measured energy.

The “heretical” literature is out there and worth knowing. The following section brings together the experimental parameters most often cited in it. One warning bears repeating. Describing how an experiment is performed gives no assurance that it works.

4 “Cook It Yourself” — An Experimental Cookbook

4.1 Preliminary Warning

What follows is an educational exercise. It describes the Fleischmann–Pons experiment and the most frequently cited variants, including the technical parameters reported in the literature. Keep three points in mind.

1. There is no universal “exact recipe.” The effect has never been reproduced reliably.
2. Most replication attempts produce no excess heat.
3. The experiment involves real hazards, including a D_2/O_2 explosion, corrosive substances, and electricity. It should be performed only in a properly equipped laboratory under supervision.

With those precautions in mind, let’s turn to the ingredients.

4.2 Safety — The Golden Rules

1. **Explosive gases.** Heavy-water electrolysis produces D_2 at the cathode and O_2 at the anode, forming an explosive mixture. Always use an open system or a catalytic recombiner. Never seal the cell airtight. Work in a fume hood.
2. **Corrosive substances.** LiOD and LiOH are strong bases. Wear gloves, safety goggles, and a lab coat.
3. **Contamination.** Ordinary water (H_2O) “poisons” the effect. Rinse all glassware with D_2O before use. Avoid contamination with H_2O and other solvents.
4. **Control.** Always run an identical reference cell with H_2O + LiOH alongside the test cell with D_2O + LiOD. The difference between the two is the signal of interest.

4.3 Ingredients and Equipment

4.3.1 The Electrolytic Cell

Component	Typical specifications	Notes
Vessel	Glass Dewar flask, 30–350 mL. The upper section (about 30%) is silvered to reduce evaporation.	The Dewar is the classic choice for calorimetry. It reduces heat losses and allows a more accurate energy balance.
Cathode (−)	High-purity palladium (Pd, ≥ 99.9%). Wire 1–2 mm in diameter, a 4 mm rod, or a 5 mm tube with a 0.5 mm wall. Typical active length is 1.2–8.5 cm.	Pd is the "pressure cooker" that must absorb deuterium into its lattice. Clean the surface. In more recent protocols, it is cold-worked (sanded, bent, and straightened repeatedly) to create crystal defects that aid absorption.
Anode (+)	Platinum (Pt) wire or coil 1 mm in diameter, wound around the cathode at a uniform spacing of a few millimeters.	Pt is inert and completes the circuit. The coil geometry distributes the electric field.
Electrolyte (test cell)	D_2O (heavy water, ≥ 99.7% purity) + 0.1 M LiOD (alternatively, 0.1–0.2 N).	LiOD makes heavy water conductive. A concentration of 0.1 M is the most common in the original work and replications.
Electrolyte (reference cell)	Distilled H_2O + 0.1 M LiOH.	Used to estimate the system's "background noise." The LiOH concentration can also be adjusted to match the conductivity of the test cell.

4.3.2 The Electrical Circuit

Component	Specifications	Notes
DC power supply	Adjustable current (galvanostatic mode) and voltage. Capable of delivering at least 2–5 A.	Constant-current operation is most common. Cell voltage depends on geometry and conductivity.
Applied voltage	Typically 8–12 V across the cell. During initiation, pulses of up to 50 V for 0.25–0.5 s can be used.	The actual voltage depends on electrode spacing, electrolyte concentration, and electrode area.
Cathodic current density	60–600 mA/cm² in typical protocols. Some protocols reach 2700 mA/cm² during intensive loading stages.	This is the key variable for "driving" deuterium into the palladium lattice.
Data logger	Multimeter or DAQ system for recording voltage, current, and temperature over time, with readings at least every 10 s.	Continuous logging is essential. A time series is needed to calculate both input and output energy.

4.3.3 Cell Diagram

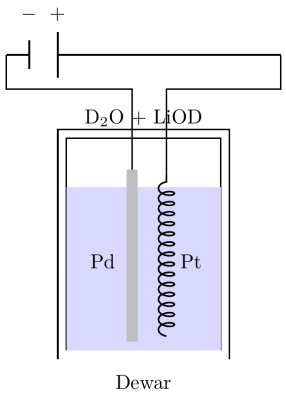


Figure 1. Simplified diagram of a Fleischmann–Pons-type electrolytic cell. The palladium cathode connects to the negative terminal and the platinum coil anode to the positive terminal. The Dewar contains D_2O + LiOD electrolyte.

4.4 Step-by-Step Procedure

4.4.1 Stage 1 — Preparing the Electrodes

1. **Clean the Pd cathode.** Polish the surface with fine abrasive paper, rinse with distilled water, and then rinse with D_2O. In more recent protocols, the wire is cold-worked by bending and straightening it repeatedly to increase the density of dislocations and vacancies in the lattice.
2. **Prepare the Pt anode.** Wind the Pt wire into a coil around the cathode, keeping a uniform spacing of a few millimeters. The spacing affects the cell voltage and field distribution.

4.4.2 Stage 2 — Setting Up the Cell

1. **Add the electrolyte.** Use **D_2O + 0.1 M LiOD** in the test cell and **H_2O + 0.1 M LiOH** in the reference cell. Typical volumes range from 30 mL in a small Dewar to 90–350 mL.
2. **Insert the electrodes.** Connect the Pd cathode to the **negative** terminal and the Pt anode to the **positive** terminal. Make sure both electrodes are well immersed and do not touch.
3. **Close the cell while leaving a gas vent.** To reduce evaporation, a layer of mineral oil or a perforated stopper can be added. Never seal the cell airtight without a recombiner.

4.4.3 Stage 3 — Electrolysis and Loading

1. **Apply current in galvanostatic mode.** Start at a moderate current density (60–100 mA/cm²) and monitor the cell voltage. It should stabilize at around 8–12 V, depending on the geometry and concentration.
2. **Load the palladium.** The atomic ratio **D/Pd** (deuterium atoms per palladium atom) must exceed a critical threshold. The literature reports that anomalous heat has never been observed below D/Pd ≈ 0.87 and that above this threshold the effect may occur. Reaching high ratios (0.9–1.1) can take anywhere from a few hours to hundreds of hours of continuous electrolysis.
3. **Charge/discharge cycles (optional).** Some protocols alternate periods of cathodic current with brief polarity reversals to “stress” the lattice and promote absorption. A recent protocol (2022) proposes three stages. (i) Use cold-worked Pd with an initial D/Pd > 0.8. (ii) Apply charge/discharge cycles to raise the average D/Pd above 0.9. (iii) Use electromigration to raise D/Pd locally to 1.14, creating a “superabundant vacancy” phase (Pd_3VacD_4) that some researchers regard as the nuclear-active environment.

4.4.4 Stage 4 — Measuring Heat

1. Record the **internal temperature** (thermocouple in the bath), **external temperature** (ambient or jacket), **voltage**, and **current** at regular intervals (e.g., every 10 s).
2. Calculate the electrical input power.

$$P_{\text{in}} = V \cdot I. \tag{1}$$

3. Calculate the thermal output power. For steady-state isoperibolic calorimetry in a Dewar, use

$$P_{\text{out}} = K(T_{\text{cell}} - T_{\text{bath}}), \tag{2}$$

where K is the heat transfer coefficient of the Dewar, determined by calibration with a heater of known power. For flow calorimetry, use

$$P_{\text{out}} = \dot{m}\, c_{\text{p}}\, \Delta T, \tag{3}$$

where $\dot{m}$ is the mass flow rate of the coolant, c_{p} is its specific heat, and ΔT is the difference in temperature between the inlet and outlet.

4. The excess power is given by

$$P_{\text{excess}} = P_{\text{out}} - P_{\text{in}}. \tag{4}$$

5. Compare with the reference cell. A significant excess should appear only in the D_2O/LiOD cell and should exceed the uncertainties estimated from the control cell.

4.5 Measurement Systems — What to Look For and What to Avoid

Parameter	Typical instrument	Points to watch
Temperature	Type K or T thermocouples, or calibrated thermistors.	Calibrate the sensors and place them at representative locations. Without stirring, temperature gradients in the Dewar can distort the readings.
Cell voltage	High-impedance digital multimeter.	Measure across the electrodes to exclude voltage drops in the leads to the power supply.
Current	Ammeter or calibrated shunt.	Check that the actual current matches the setpoint.
Gases evolved	Flowmeter or recombination system.	In an open system, D_2 and O_2 are released. Their flow rate gives an indirect indication of the reaction rate.
Nuclear by-products (optional)	Neutron detectors, and a mass spectrometer for helium and tritium.	Fleischmann and Pons reported traces of ^{4}He and tritium. These results have yet to be reliably replicated.

4.6 The “Chef’s Secrets”

- **Palladium varies.** Its microstructure (grains, dislocations, and vacancies) affects its ability to absorb deuterium. Some researchers obtain better results with cold-worked Pd or electrodeposited thin films.
- **The D/Pd threshold.** A D/Pd ratio above 0.87 is reported as a necessary condition. The farther the ratio exceeds this threshold, the more likely anomalous heat is said to be, though the effect remains uncertain.
- **“Poisoning” by ordinary water.** Even small amounts of H_2O contamination can suppress the signal. Use high-purity D_2O ($\geq 99.7\%$) and work in a clean environment.
- **Patience.** When the effect does occur, it can take hundreds of hours of electrolysis. Allow more than an afternoon for the experiment.
- **The control cell.** A reference cell containing H_2O/LiOH is essential for interpreting any excess heat measurement.

5 Conclusions

Cold fusion remains one of the most controversial chapters in twentieth-century science. This cookbook describes how the experiment was performed and which conditions have been identified as necessary. It offers no guarantee of a result. The vast majority of replications have produced no significant excess heat, and the phenomenon has yet to be demonstrated unequivocally.

The episode offers a valuable lesson in method. Calorimetry is difficult, reproducibility is essential, and rushing to the press can do serious harm to science. Whether LENR eventually proves to be a real phenomenon or a collective error, the way it has been, and continues to be, investigated remains a fascinating case study.

Final Warnings

WARNING — Disclaimer

1. **No guarantee of success.** This document describes a historical experiment and its variants. The protocol remains unvalidated.
2. **Explosion hazard.** A D_2/O_2 mixture is explosive. Use open systems or recombiners and never seal the cell.
3. **Chemical hazard.** LiOD and LiOH are corrosive. Wear gloves, safety goggles, and a lab coat.
4. **Properly equipped laboratory only.** Perform the experiment under supervision, with suitable electrical and ventilation systems.
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Manuele Turini — 12 November 2026

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