Review of 1989 and 2004 DOE Reports

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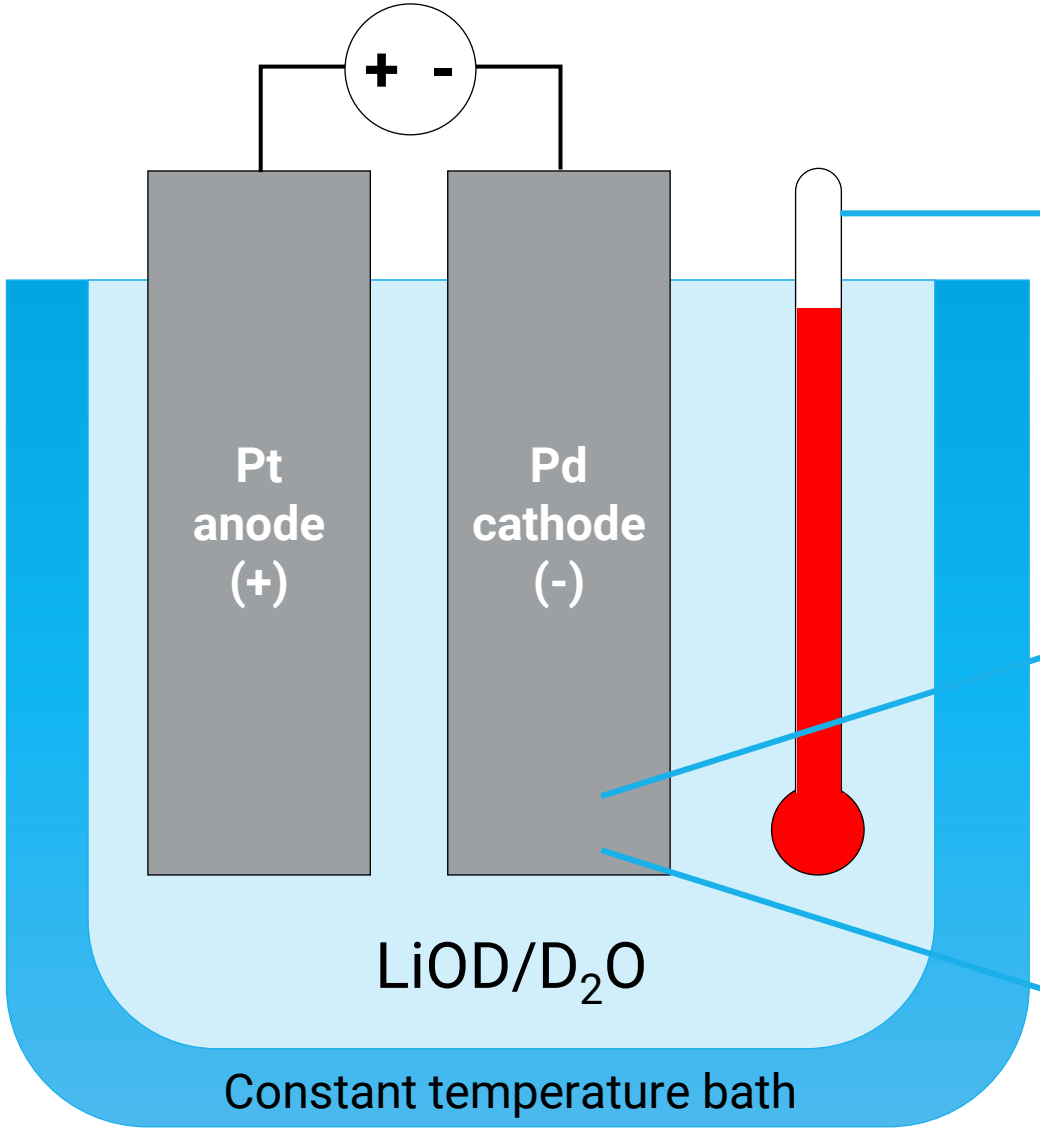
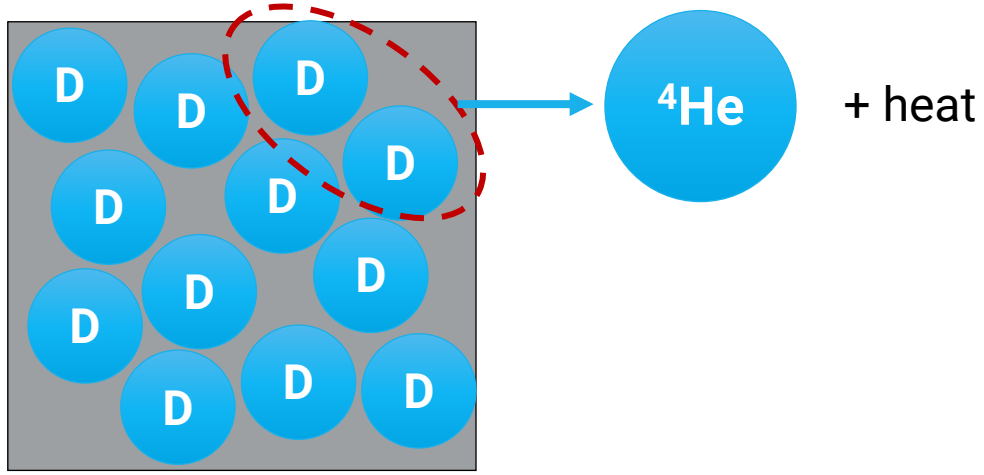
Where it started*: the Fleischmann & Pons experiment (1989)



Observation: Excess heat (30 °C → 50 °C)

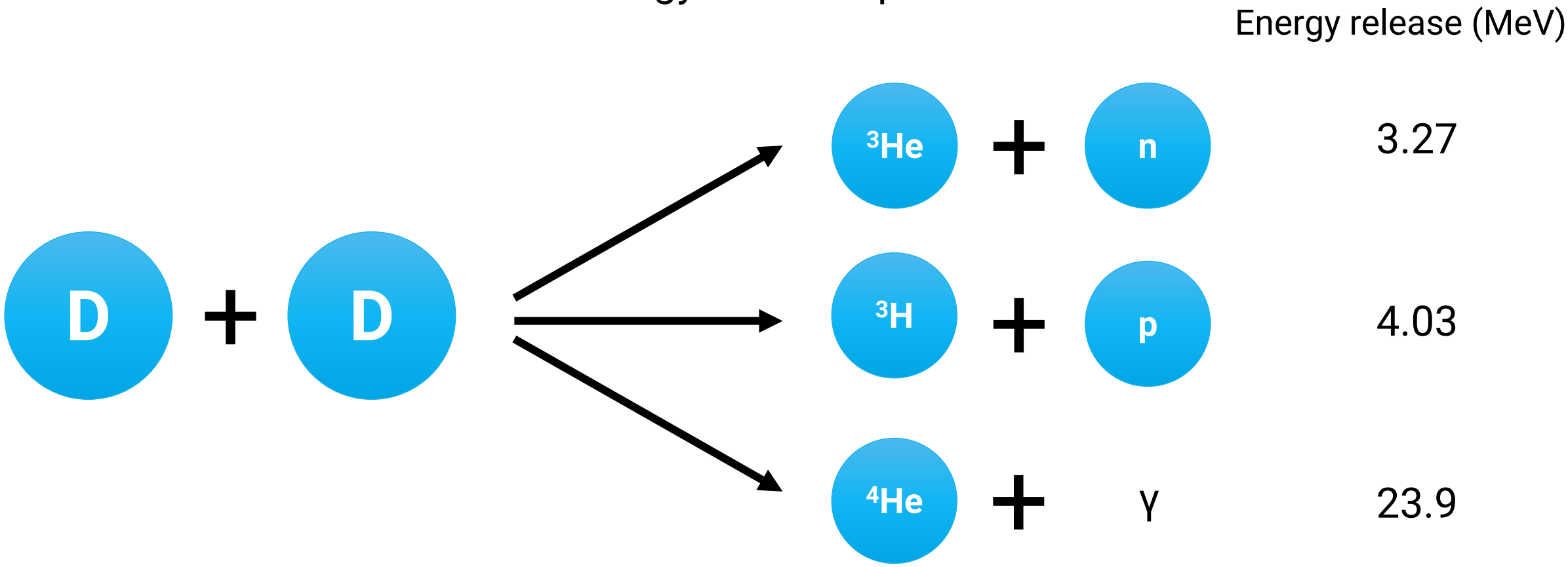
Hypothesis: D+D fusion responsible for excess heat



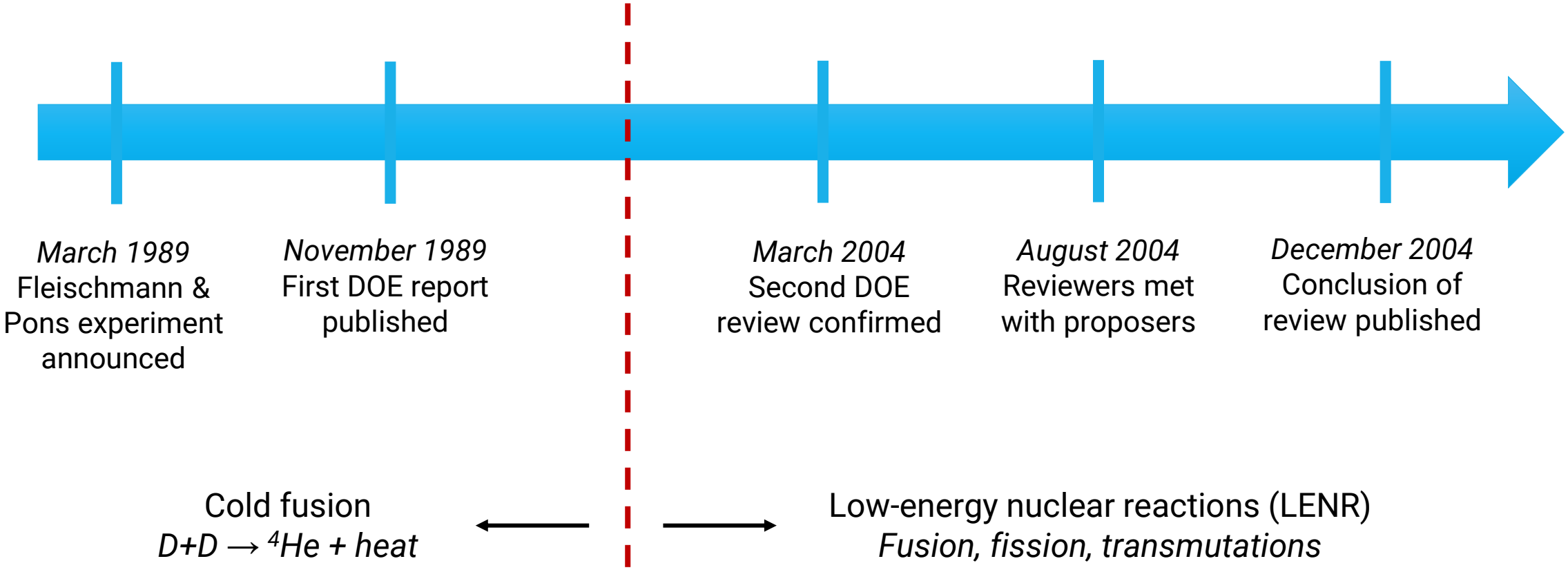
*There were reports of LENR experiments as early as 1920s, but the Fleischmann & Pons experiment is the most famous

Potential impact of “cold fusion”

- *Nuclear:* ~1-10 MeV of energy released per reaction
- *Chemical:* ~1× 10^{-6} MeV of energy released per reaction



Timeline of DOE reports



1989 DOE REPORT

Panel background and process

- Energy Research Advisory Board (ERAB) panel
- 25 panel members
- Purpose to “assess possibility of cold fusion”
- Review lasted for 6 months
  - Participated in Workshop on Cold Fusion May 1989
  - Visited 6 laboratories
  - 114+ journal articles, preprints, and communications studied
  - 5 public meetings held where findings were discussed, drafts of interim and final reports formulated

Main assertions

1. Experiments do not present convincing evidence to associate anomalous heat with a nuclear process

2. Present evidence for a new nuclear process termed cold fusion not persuasive

3. Experimental results do not present convincing evidence that useful sources of energy can be obtained from cold fusion

*The 1989 review used understanding of hot fusion mechanism as basis for these assertions.

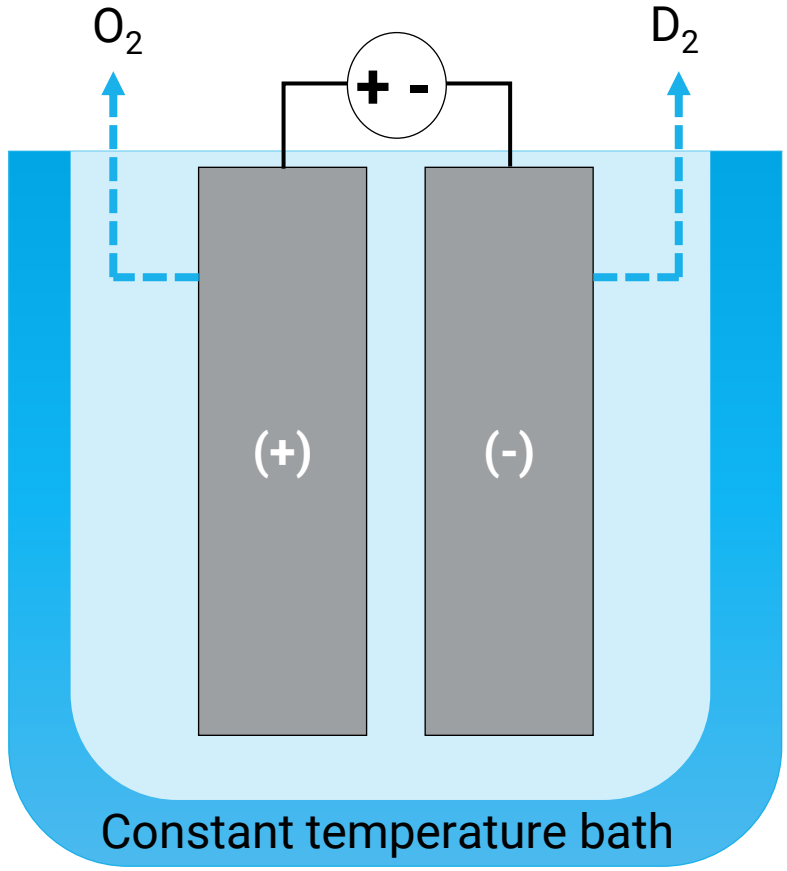
Excess heat is not reported in the majority of experiments

- 13/18 experiments do not report excess heat
  - Most positive results in open systems

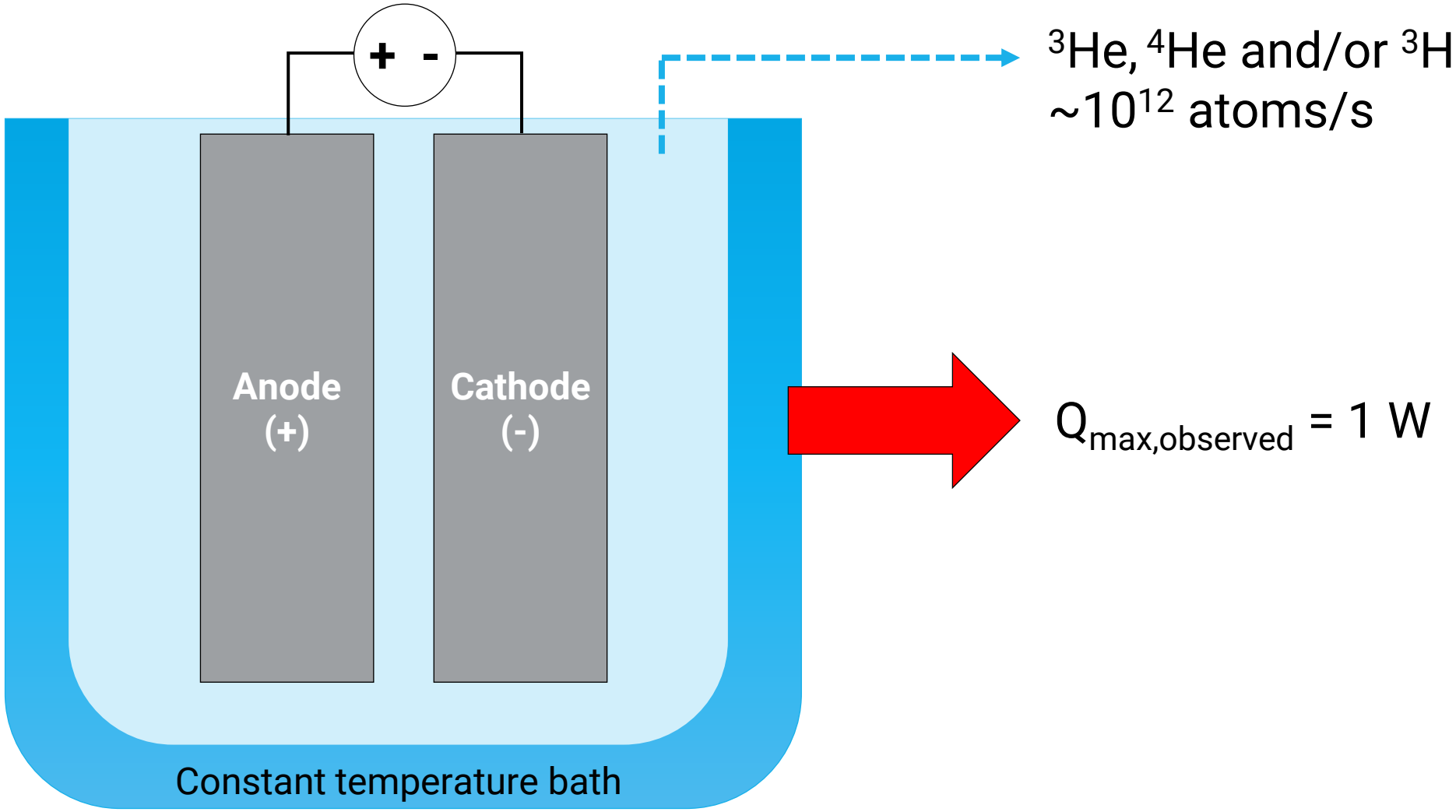
- Energy balance, open system (assuming no fusion):

$$P_{out} = P_{in} - \underbrace{P_{f,D2O}}_{1.527\ V * I}$$

- P_{excess} << 1.527 V * I
- Calls assumption of no O_2/D_2 recombination into question



When excess heat is reported, there are a lack of fusion products



Internal inconsistencies and lack of reproducibility hinder understanding

Variations in experimental set-up may be responsible for failure to observe excess heat

- Different Pd materials
- Source and batch of D_2O
- Size of electrode
- Insufficient electrolysis time
- Too small current density
- Unknown effect of impurities or electrode surface conditions

Errors in measurement may be responsible for anomalous heat

- Calorimetry measurements are difficult
- In most cases, excess heat is small and may be within error of the measurement

Consensus: Poor experimental design, documentation, and background control hamper understanding and interpretation of results

Main assertions

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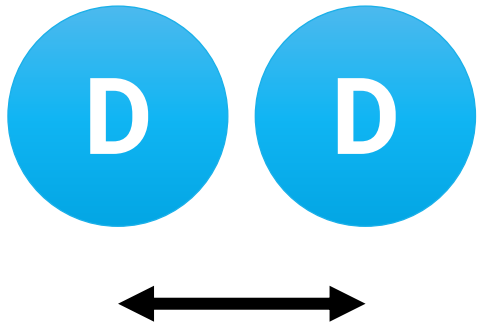
Absorbed atoms are too far apart for fusion to occur

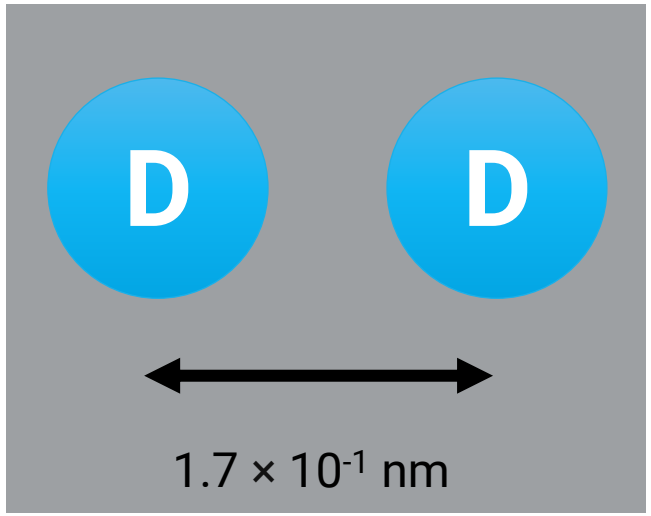
Electron tunneling



10^{-5} nm

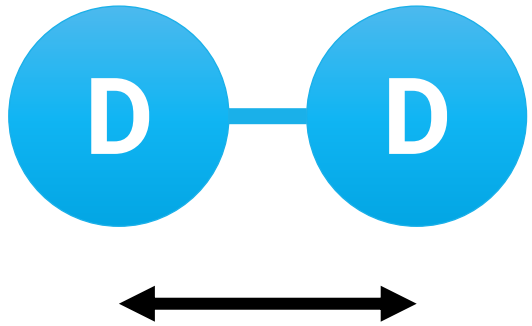
Typical distance required for fusion (overcome Coulomb barrier)

Pd-absorbed D atoms



Smallest distance between interstitial sites occupied by D atoms

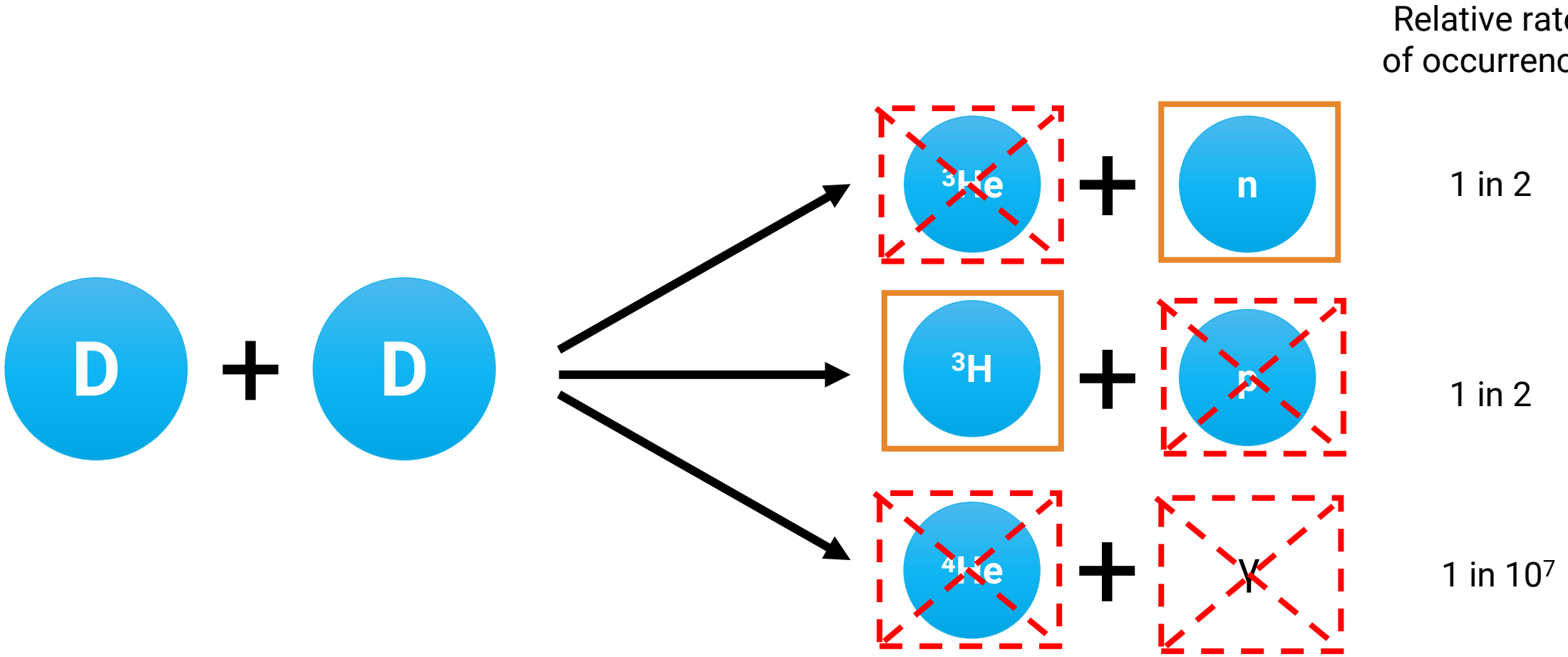
D-D molecule



0.74×10^{-1} nm

Rate of D-D molecule fusion: 1 per year in solar mass of D_2

Lack of primary & secondary nuclear particles rules out known D-D fusion mechanism



- Bursts of ^{3}H occasionally observed; not replicable
- All experimental measurements give upper limit of neutrons much smaller than expected for equivalent excess heat production

Main assertions

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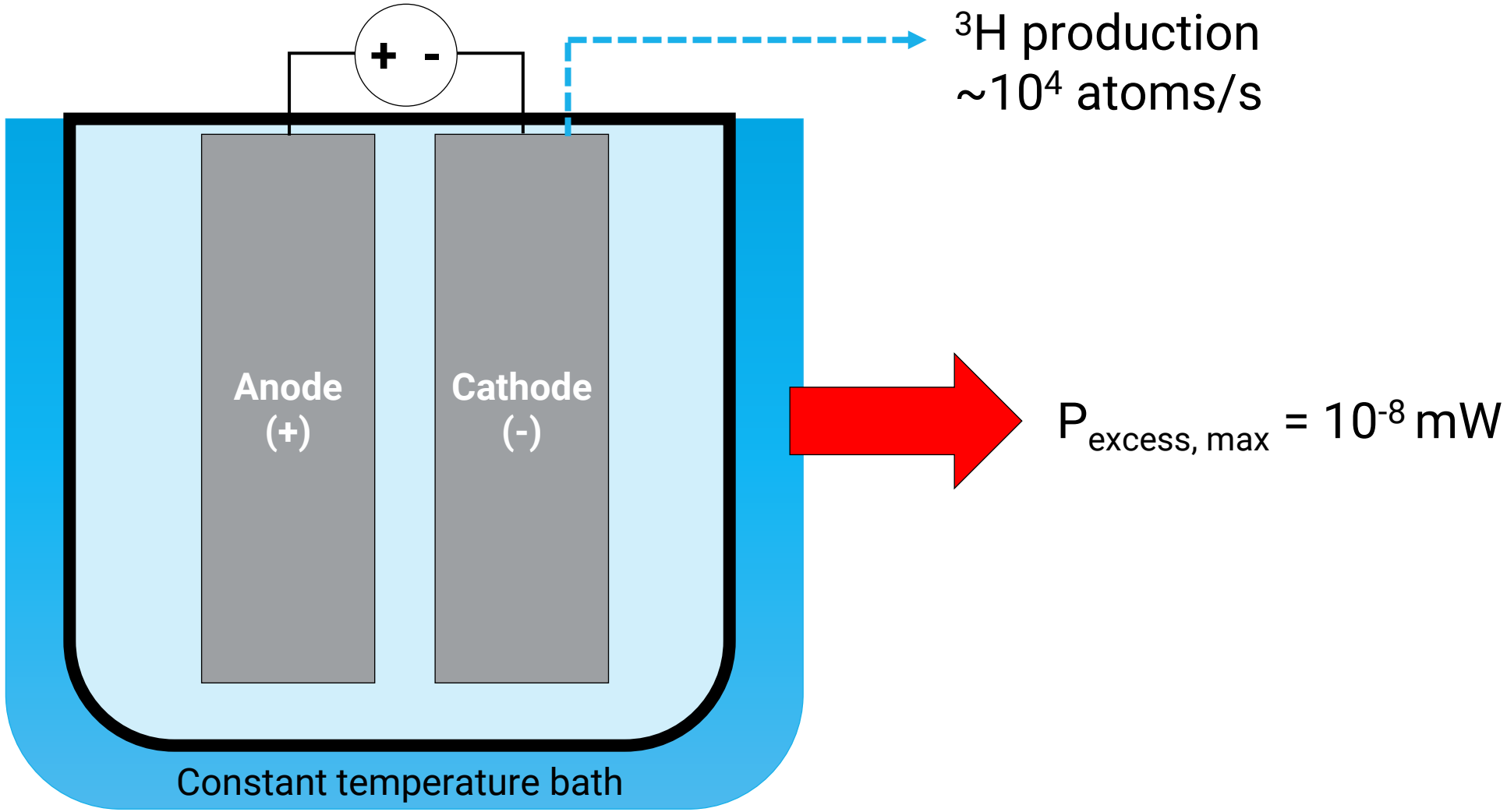
Claims of fusion products at low levels have no apparent application to production of useful energy



Panel recommended against special funding of cold fusion

- Recommends against establishment of special programs or research centers to develop cold fusion
- Supports funding of cooperative, focused, peer-reviewed experiments for further investigation
- Recommends research efforts primarily focusing on confirming or disproving excess heat, with emphasis on fusion products observed

2004 DOE REPORT

Review Background and Process

- 2003: group of scientists requested DOE revisit scientific evidence for LENR
- July 2004: Review document submitted that identified most significant experimental observations and publications – “New Physical Effects in Metal Deuterides”
  - 9 scientists conducted peer review of report
- August 23, 2004: One day review
  - 6 research groups gave oral presentations on work in their labs
  - 9 additional scientists participated in review panel

Review criteria

1. To examine and evaluate the experimental and theoretical evidence for the occurrences of nuclear reactions in condensed matter at low energies

2. To determine whether the evidence is sufficiently conclusive to demonstrate that such nuclear reactions occur

3. To determine whether there is a scientific case for continued efforts in these studies, and, if so, to identify the most promising areas to be pursued

Charge 1: Experimental and theoretical evidence for LENR

<u>Argument #1:</u> Excess power from electrolytic cells

- Excess power observed beyond that attributable to ordinary chemical or solid state sources

- Effect is observed often
- Is compelling under some understood conditions

- Not clear that excess power is produced when integrated over experiment lifetime
- All possible chemical and solid-state causes have not been investigated and eliminated
- Excess power is a few percent of external power; hence calibration and systematic effects may be responsible

<u>Argument #2:</u> Evidence of expected fusion products

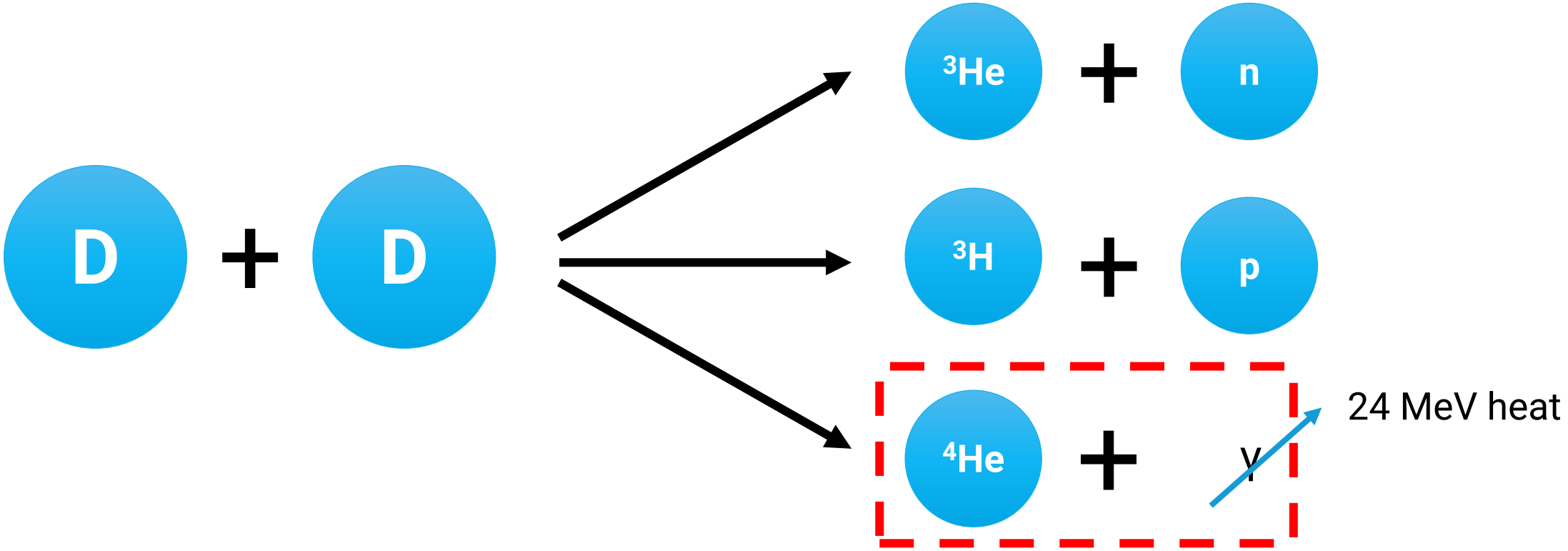
- ^{4}He found in 5/16 cases where cells produced excess heat

- Detected ^{4}He above background levels

- Levels reported close to background levels, contamination of apparatus cited as possible cause
- Lack of consistency indication that overall hypothesis not justified

Consensus: Poor experimental design, documentation, and background control hamper understanding and interpretation of results

Charge 2: Evidence to conclusively demonstrate that low energy nuclear reactions occur



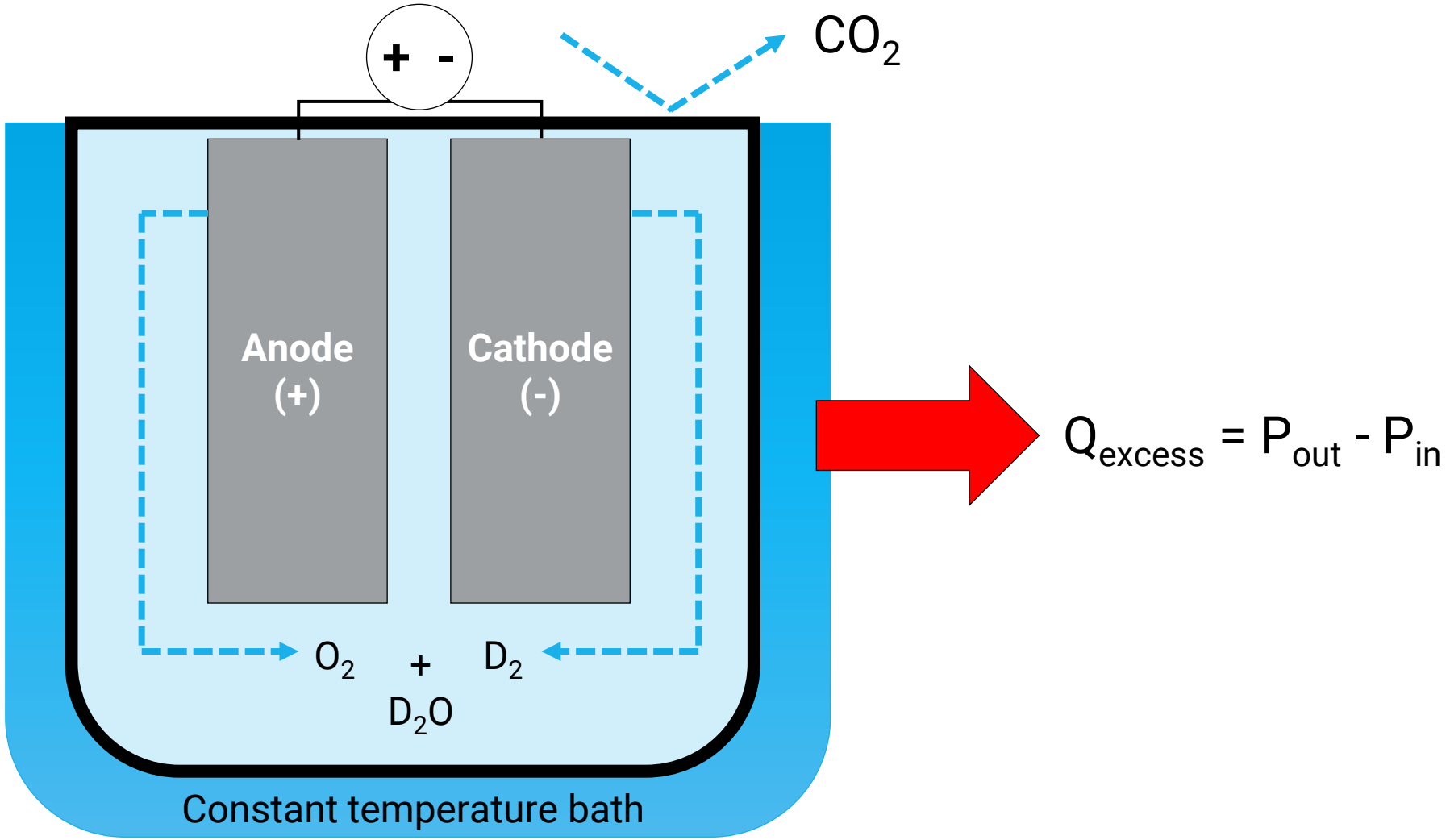
- Serious concerns raised about assumptions postulated in the proposed theoretical framework
- **Consensus**: Majority of reviewers stated evidence not conclusively demonstrated, 1 reviewer said it was conclusively demonstrated

Charge 3: Scientific case for continued efforts, and what are most promising areas

- No reviewer recommended federally funded program for LENR
- Nearly unanimous: funding agencies should entertain individual, well designed-proposals
  - Whether or not there is anomalous energy production in Pd/D systems
  - Whether or not D-D fusion reactions occur at energies ~eV

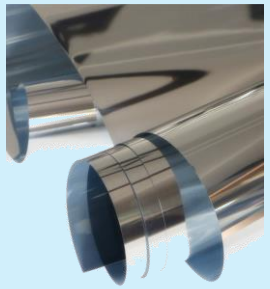
RECOMMENDATIONS & TAKEAWAYS FOR FUTURE WORK

Experiments should be performed in closed systems

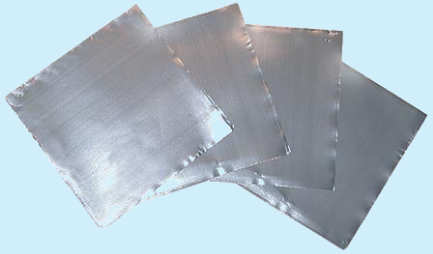


Consistency and reproducibility are key

Experimental conditions must be consistent



Electrode materials



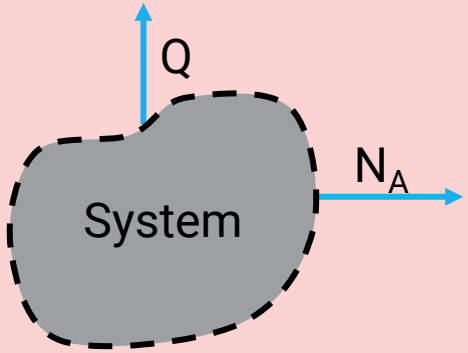
Electrode size

Electrolysis time

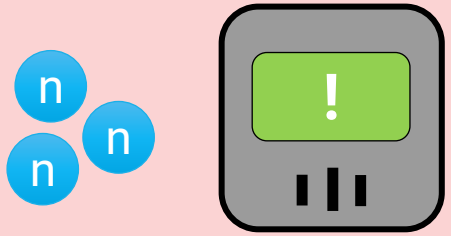
Current density

Electrolyte

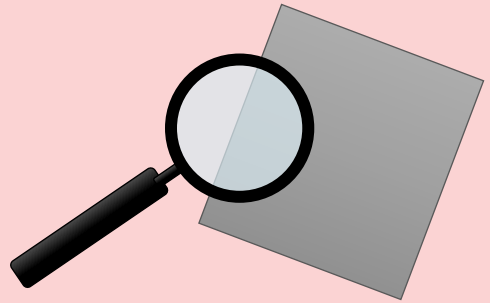
Experiments must be reproducible, and methods clearly reported



Mass and energy balances



Secondary product detection



Material analysis of cathode

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