Cold Fusion
Without Neutrons?

Non l'avrei mai creduto...
Ma farò quel che potrò...

Don Giovanni
Act III

A few theoretical considerations by
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1. Cold fusion
2. Nuclear Reactions & Rates
3. Neutronless fusion?
4. Open questions
Cold Fusion?

Facts: Fleischmann & Pons:

\[
\begin{align*}
\text{Heat} & : 10^{14} \text{ joules/sec} \implies T \text{ pair } = 10^{-10} \text{ sec} \\
\text{Neutrons} & : 10^8 \text{ n/sec} \implies \Gamma (n) = 10^{-20} \text{ sec} \\
\text{Jones et al.} & \\
\text{Neutrons} & : \Gamma \text{ pair } = 10^{-20} - 10^{-15} \text{ sec}^{-1}
\end{align*}
\]

Atomic scales

\[
R \sim 1 \text{ Å} \\
E \sim 1\text{–}5 \text{ eV}
\]

Nuclear scales

\[
1 \text{ Fm} = 10^{-5} \text{ Å} \\
1 \text{ MeV} = 10^6 \text{ eV}
\]

\[
V = \frac{Z_1 Z_2 e^2}{(1 \text{ Fm})} \sim \text{ MeV} \left( \times 10^{10} \text{ eV} \right)
\]

How can they talk to each other at room temperature??
A simple exercise

- Gerskii, Feldman
- Bacci & Fioretti
- Van Hove & Jaksic 1975 (Dz)
- Kalvastu et al.

Potential Energy

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Localised in a region \( \sim R \) (static/dynamic)

\[ \Gamma' = p \sigma v \]

\[ p = \frac{1}{R^3} w(R) \]

\[ w(R) = \exp \left[ - \pi \frac{\sqrt{\beta, \gamma, \alpha, \nu}}{137} R \right] \]

What values of \( R \) give the desired pair? ??
A more realistic picture

Potential Energy

mountain's top \( E \approx 10^4 \text{ eV} \)

"bare"

Coulomb potential \( \leftrightarrow \) reliable here

electron screening

Equilibrium position etc.
Crude estimate for large $R$

$w = e^{-\lambda}$

$\lambda(0.74 \text{ Å}) \approx 225$

(From Sixten & Jones)

$\Rightarrow \lambda \propto \frac{1}{R} \approx 2.6c$

but should be, not bad for $R \approx 0.1 \text{ Å}$
2. Nuclear Reactions & Rates

- \( W(R) \) a very steep function of \( \rho, \mu, \tau, \lambda \)

- \( R \uparrow \) \( w \uparrow \)

- \( \rho \uparrow \) \( w \uparrow \)

- \( \frac{Z}{A} \uparrow \) \( w \downarrow \)

-only light particleskimmel reasonably

- very few reactions are realistic candidates:

- \( p + p \rightarrow d + e^+ + \nu_e \) weak interaction

- \( p + d \rightarrow ^3\text{He} + \gamma \) (5.44MeV) elastic interaction

- suppressed by \( \approx 10^{-4} \) in vacuum

- \( \sigma \) \( (p+d \rightarrow ^3\text{He} + \gamma) \approx 10^{-6} \times 10^{23} \) (see later)

- \( \sigma \) \( (p+d \rightarrow ^3\text{He} + n) \approx 1 \times 10^{23} \) " "

- [Tousi, E., 1972]
\[ P + D \rightarrow ^3\text{He} + \gamma \]
\[ D + D \rightarrow ^3\text{He} + n \]
\[ P + ^7\text{Li} \rightarrow ^4\text{He} + ^4\text{He} \]

\[ E = 36\text{eV}, 150\text{eV} \]

\[ \Gamma(P + D) \approx 10^{-12} \text{sec}^{-1} \]
\[ \Gamma(D + D) \approx 10^{-11} \text{sec}^{-1} \]
\[ \Gamma(P + D) \approx 10^{-24} \text{sec}^{-1} \]
\[ \Gamma(D + D) \approx 10^{-25} \text{sec}^{-1} \]
Moral of the exercise

- $\tau \propto 10^{-20} \div 10^{-23} \text{ sec}^{-1} \iff \{ R \approx 5 \times 10^{-8} \text{ A} \}
  \{ \tilde{E} \approx 1.5 \text{ keV} \}$
- $\tau_{FP} \approx 10^{-10} \text{ sec}^{-1} \iff \{ R \approx 5 \times 10^{-8} \text{ A} \}
  \{ \tilde{E} \approx 300 \text{ eV} \}$

[Titus et al.: R \approx 3 \text{ A}^2
  but still \tilde{E} \approx 100 \text{ keV}]

This is very encouraging: conceivable that $R$ can be obtained by atomic phenomena [hard but...]

- Most likely not an equilibrium situation i.e. not from bulk

(FSP seem to observe volume effect)

however effective surface may be fractal: surface \( \propto l^{2+d} \) \( d \approx 0.5 \)

\( E \approx 10^2 \text{ eV} \) may be given by surface discharges (G. Parisi)

- Forget $\text{P + Li}$; $\text{Li + Li}$... reactions

- Can Nuclear Physics be affected??

(see below)
3. Neutroless fusion

\[ \frac{5 \times 10^5}{10^4} \text{ neutrons/sec} \]

\[ \text{for } 10^{24} \text{ pair } \Rightarrow \Gamma \text{ (neutron)} = 10^{-19} \div 10^{-30} \text{ sec}^{-1} \]

This agrees \approx with Jones.

Can there be another reaction, such present/seen in Tous's expl.

Enhanced by 10^9??

1) \[ \text{D} + \text{D} \rightarrow ^4 \text{He} + \text{ "photon"} \]

i.e. momentum taken by surrounding

\[ \text{hardly } 0 < \Gamma < 10^{23} \text{ (sec)}^{-3} \]

\[ \frac{\text{sec}^2}{\text{sec}^2} \]

unless a very sharp resonance (not repeated on Tables)

2) Tunnelling can give large factors:

\[ \frac{W_{\text{D} + \text{D}} (0.1 \text{ A})}{W_{\text{D} + \text{D}} (0.1 \text{ A})} \approx 10^6 \]

Problem - fusion: can it be?
in vacuum: \( \text{P} + \text{D} \rightarrow ^3\text{He} + \gamma \)

- rate \( n \times 10^{-6} \) of \( \text{D} + \text{D} \)
- 5 MeV \( \gamma \)'s: unseen?

- However:

\[
P + D \rightarrow ^3\text{He} + \text{"surrounding"}
\]

at \( 5 \times 10^{23} / \text{sec} \)

this could be interesting

- "surrounding" : the only thing I can think of
- Super electrons

\[
P + D + e \rightarrow ^3\text{He} + e
\]

\[
\begin{align*}
\text{D} & \quad \rightarrow \quad ^3\text{He} \\
\text{P} & \quad \rightarrow \quad e
\end{align*}
\]

is it reasonable?

\[
\text{FSP:} \quad \frac{\hbar}{\text{D}} \times 5 \times 10^{-19}
\]

[is it true?]

- "surrounding" = phonous I think unlikely

\( R = 0.1 \text{ Å} \)
4. Open Questions

- \( \Gamma \) (reaction): not very special effects are required.
  \[ E_n = 6.1 \text{ A} \] still not easy.
  \[ E_n = 150 \text{ eV} \] easy.

- \( \Gamma \) (fraction) \( \exp \) : a mystery
  (P+D fraction?)
  Auger effect?

- Suggestion: look for P+D \( \rightarrow \) He\(^{3+}\)
  as frequent than D+D
  \( \sim 1 \% \) at \( 6.1 \text{ A} \)
  [universe]?

- ratio P+D/D+D \( \Rightarrow \) a very sensitive
  measure of \( R \)

- if absent at the above level would suggest some form of "quenching" due
to surrounding.

- Cold fusion: here to stay? Maybe
- Somebody is going to eat his hat