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Nuclear Reactions of Cold Fusion - A systematic Study

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Abstract
A computer is used make an exhaustive search for simple nuclear reactions between naturally occurring isotopes with a view to identifying possible primary cold fusion reactions and materials which might support theoretical models. We discuss the difficulties in producing neutrons and tritium in light water experiments.

1. Introduction
Despite substantial progress made in demonstrating Cold Fusion phenomena, it is still not clear what nuclear reactions, if any, are taking place. Many workers have reported small quantities of possible products including neutrons, tritium, helium isotopes and other unidentified short lived radioactive isotopes. No systematic pattern has emerged, but it has been suggested independently by various workers[8,10] that the usual nuclear parameters reaction energy, spin and parity conservation are important criteria.

We have created a simple database of some 2400 atomic weights and nuclear spins and parities[7] on a personal computer. Many sources of atomic data contain significant errors, so we first checked the atomic weights for consistency by performing a least squares fit to a model independent equation of the form:

$$A.W. = g_1(Z)+g_2(N)+g_3(N+Z)+g_4(N-Z)$$

where g_n are four arrays for a total of 570 coefficients. The average error was 10^{-4} amu, about an order of magnitude more accurate than the semi-empirical liquid drop formulae. A simpler version of this formula was first proposed by Garvey et al in 1969[13] when it was not possible to solve the 570 simultaneous equations on available computers!

The program searches for generic reactions limited to 1 or two reactants and / or products:-

$$R + S \rightarrow P + Q \quad (1)$$

where R and S are one of the 278 naturally occurring nuclides and P and Q are nuclear products such as tritium, neutron, helium isotopes. We assume that any weak interactions will be insignificant (excepting possible decay of P and Q) and therefore the number of neutrons and protons in the system are conserved.

2. Selection Criteria
Only exothermic reactions are considered involving naturally occurring nuclides. In order to reduce the number of possibilities further we may need to suppose that[8] the products are stable to beta decay, and nuclear spin and parity are conserved.

Apart from the laws of physics, we can impose criteria on the basis of possible reactants, such as the materials constituting the cold fusion system. Alternatively we can examine those reactions which produce a specific product such as He, tritium or neutrons.

3.0 Product Oriented Approach
The approach of searching for reactions which generate specific products does not give many positive results. For example ^{4}He can be formed in hundreds of different reactions between natural nuclides and hydrogen isotopes. Consequently the detection of helium alone, even quantities commensurate with heat production is not definitive evidence of simple deuterium fusion, nor indeed of any other specific reaction. Identical arguments apply to neutron production in deuterium systems. In contrast ^{3}He and tritium production from deuterium are limited to a dozen or so simple reactions, and results are published elsewhere[16]. However such products cannot be part of any major reaction not being commensurate with heat production.

3.1 Light Hydrogen Systems

The product oriented approach can usefully concentrate on neutron and tritium production from protium with interesting negative results. The computer finds **no** simple exothermic reactions of the form:

$$^{1}H + {}^{A}R \rightarrow {}^{3}H + {}^{A-2}P \quad (2)$$

At least two independent groups have detected tritium production in light water electrolysis[4,5]!

We find only one exothermic neutron producing reaction:

$$^{1}H + {}^{40}K \rightarrow {}^{1}n + {}^{40}Ca \quad +0.530 \text{ Mev}$$

We should not be surprised that such reactions are rare, as they must be endothermic for all beta stable nuclei. There are few naturally occurring beta unstable isotopes, and ^{40}K with a half life of about 10^9 years is one of them. However there may be some difficulty with ^{40}K as a source of neutron production in light hydrogen experiments[6,17]. Firstly the above reaction does not conserve nuclear spin nor parity so the neutron production channel will be strongly suppressed. ^{40}K constitutes only one part in ten thousand of natural potassium. Finally, there is no reason to suppose that any potassium was present in the experiments.

Bush[14] has reported the detection of both the above strontium isotopes in same isotopic proportions as natural rubidium. The different spin changes suggest that the rate of fusion will be different for the two rubidium isotopes, and one presumes that any cold fusion is occurring in a very limited zone where essentially all the rubidium is being transmuted! An alternative explanation is that the two rubidium isotopes are transmuted by neutron transfer (as discussed subsequently in this paper) which then beta decay to strontium. In this case there are no unfavourable spin changes, and one would expect tiny quantities of ^{86}Kr also as an minor decay product of ^{86}Rb.

Bush has also extended the Cold Alkali Fusion, CAF hypothesis to hydrogen fusion with other nuclides and suggests that the reaction energy is an important criterion. The author has discussed this idea elsewhere[15].

4. Palladium Fission

In 1992 Karabut et al.[8] reported unexpected quantities of Na, Mg, Al, Si, S, Ca, Ti, Cr, Fe, Ni, Zn, Ge, Br, Sr, Mo after glow discharge of deuterium gas between palladium electrodes and tentatively suggested fission as an explanation. They excluded simple reactions of type (1) for R=deuterium on the grounds of conservation laws cited previously. However the following reactions do conserve spin and parity and produce stable products:

$^{1}H + {}^{102}Pd \rightarrow$	$^{19}F + {}^{84}Sr$	+1.49 MeV
$^{1}H + {}^{104}Pd \rightarrow$	$^{19}F + {}^{86}Sr$	+3.90 MeV
$^{1}H + {}^{106}Pd \rightarrow$	$^{19}F + {}^{88}Sr$	+6.78 MeV
$^{2}H + {}^{106}Pd \rightarrow$	$^{14}N + {}^{94}Zr$	+7.63 MeV
$^{1}H + {}^{105}Pd \rightarrow$	$^{23}Na + {}^{83}Kr$	+8.38 MeV
$^{2}H + {}^{104}Pd \rightarrow$	$^{14}N + {}^{92}Zr$	+9.33 MeV
$^{2}H + {}^{102}Pd \rightarrow$	$^{14}N + {}^{90}Zr$	+11.11 MeV
$^{1}H + {}^{106}Pd \rightarrow$	$^{31}P + {}^{76}Ge$	+15.03 MeV
$^{1}H + {}^{104}Pd \rightarrow$	$^{31}P + {}^{74}Ge$	+15.76 MeV
$^{1}H + {}^{102}Pd \rightarrow$	$^{31}P + {}^{72}Ge$	+16.39 MeV
$^{2}H + {}^{105}Pd \rightarrow$	$^{23}Na + {}^{84}Kr$	+16.68 MeV
$^{2}H + {}^{105}Pd \rightarrow$	$^{37}Cl + {}^{70}Zn$	+26.04 MeV
$^{2}H + {}^{102}Pd \rightarrow$	$^{49}Ti + {}^{55}Mn$	+31 47 MeV

Absent from this list are Mg, Al, Si, S, Ca, Cr, Fe, Ni, Mo. Perhaps the selection criteria may be excessively restrictive. Relaxing spin conservation we could expect Ni, Cr, Mo, Al, Se, B as additional stable products. In 1993 Karabut et al.[9] reported more refined detection of palladium "impurities" after glow discharge including isotope shifts in He, Li, C, K, Zr.

A difficulty with the fusion / fission approach is that even if the hydrogen nuclide can penetrate the Coulomb barrier, an intermediate silver nucleus is unlikely to be sufficiently excited to break up into fission fragments. On the other hand results of other workers at this conference do lend experimental support for transmutations (ie Dash J, Wolf K., George R.).

5.0 Polyneutrons

Fisher has proposed the involvement of neutral hypothetical poly-neutrons agents in an attempt to overcome the usual objections of Coulomb and other energy barriers to Cold Fusion[3]. The hypothesis explains the sporadicity of heat production and the substantial absence of gamma rays. Poly-neutrons are speculated to be generated from super heavy hydrogen isotopes present in water and concentrated with deuterium. In contrast to other the neutron transfer theories, the role of hydrogen isotopes is explained.

Excess heat is speculated to be produced by poly-neutron growth by the exchange of neutron pairs. The computer compiles the following table of isotopes which can accept neutron pairs yielding some 11 MeV or less (these isotopes should not allow ^{6}n shrinkage).

	Accept MeV	Donate MeV	Neutron X Section barns	Abund. %
^{1}H	8.4	-	.332	100
^{4}He	0.9	-28.3	0	100
^{6}Li	9.2	-31.8	941*	7.5
^{7}Li	6.0	-12.9	.0395	92.5*
^{9}Be	7.3	-20.5	.0081	100
^{11}B	8.2	-19.8	.00053	80.1*
^{13}C	9.3	-23.6	.00141	1.1*
^{15}N	8.3	-21.3	.000041	0.372*
^{136}Xe	9.8	-14.4	.262	8.9*
^{208}Pb	9.1	-14.1	.00493	52.4*
^{209}Bi	9.7	-14.3	.011	100
^{232}Th	10.9	-11.5	7.347	100
^{238}U	10.7	-11.2	2.71	99.3

However the lighter nuclides, with the exception of ^{7}Li cannot assist in ^{6}n growth because they cannot donate a pair of neutrons for 15 MeV or less. ^{6}Li has a high neutron absorption cross-section and would be expected to poison polyneutron creation. In the table an asterisk (*) indicates an unsuitable parameter.

The best materials appear to be Bi, Th and U. However the fact that deuterides of these metals have been successfully prepared in the laboratory without noticeable effects[12] suggests that any successfully poly-neutron theory may require modification. Both thorium and uranium hydrides (deuterides) are pyrophoric - they catch fire spontaneously in air. It is quite possible that any anomalous heat production may have been discounted as being due to atmospheric contamination. Similarly, any radioactivity could be discounted as being natural.

The polyneutron theory can explain both the creation of neutrons and tritium in light water experiments. Neutrons are predicted to be created in bursts as a result of ^{4}n decay. Tritium may be created when an excited poly-neutron donates a pair of neutrons to protium. The theory predicts neutron amplification now verified experimentally[11].

6.0 Neutron Transfer

According to Hagelstein[2], neutrons may be able to hop from one nucleus to another in the lattice. Such a possibility is conjectured to be favoured if spin and parity are conserved for the production and absorption of the free virtual s-wave neutron and if the overall reaction energy is small (near resonance). The computer finds these reactions:

^{37}Cl	+ ^{195}Pt	->	^{38}Cl + ^{194}Pt		+3 keV
^{85}Rb	+ ^{184}Os	->	^{86}Rb + ^{183}Os		+3 keV
^{70}Ge	+ ^{184}W	->	^{71}Ge + ^{183}W		+4 keV
^{204}Hg	+ ^{6}Li	->	^{205}Hg + ^{5}Li		+4 keV
^{76}Se	+ ^{184}W	->	^{77}Se + ^{183}W		+7 keV
^{125}Te	+ ^{120}Sn	->	^{126}Te + ^{119}Sn		+7 keV
^{117}Sn	+ ^{103}Rh	->	^{118}Sn + ^{102}Rh		+8 keV
^{199}Hg	+ ^{172}Yb	->	^{200}Hg + ^{171}Yb		+9 keV
^{69}Ga	+ ^{57}Fe	->	^{70}Ga + ^{56}Fe		+9 keV

Given that atomic weights are generally not known much more accurately than 10 keV, the actual reaction energies are approximate. The reaction rate is enhanced if the energy is low due to possible resonance. Reaction energy of say 1 keV requires some 10^{15} atomic products per Joule which have never been detected. Consequently some other reaction is required for power production and in the above table the decay of ^{5}Li would seem a good candidate. This decay is extremely fast and produces no gamma rays and could explain ^{4}He production. However such decays, may produce at least X-rays, and these are lacking.

In the latest version of the neutron transfer theory, possible donor elements ^{A}X should have a naturally occurring sister isotope $^{A-1}$X which can accept the neutron with perfect energy matching, (resonance). This and the s-wave requirement cast some doubt on the above table and the only permitted donor isotopes will be: ^{2}H, ^{4}He, ^{29}Si, ^{30}Si, ^{111}Cd, ^{112}Cd, ^{112}Cd, ^{115}Sn, ^{116}Sn, ^{117}Sn, ^{118}Sn, ^{119}Sn, ^{120}Sn, ^{125}Te, ^{126}Te, ^{129}Xe, ^{130}Xe. In addition to the above donor elements, acceptors can be Mg, Al, P, Cl, As, Rb, Mo, Cs, Ba, Yb, Th. Note the absence of Pd and Ni from this list.

Conclusions

A computer is ideally suited to scanning through many reactions to select possibilities for more detailed study. By eliminating all simple reactions of type (2) for the production of neutrons and tritium, we can focus attention on other possibilities including error which otherwise might have seemed improbable. Reactions with more than two products have been excluded from this study. But the fission of any sufficiently heavy nucleus can yield multiple products including neutrons and tritium. The identification of potential materials to demonstrate specific theories may stimulate further experimental and theoretical research.

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