J. Condensed Matter Nucl. Sci. 40 (2025) 21–39

Research Article

Thermodynamics in Lattice Assisted Nuclear Reactions

Mitchell R. Swartz, ScD, EE, MD

JET Energy, Inc., Wellesley, MA USA

Abstract

Thermodynamics studies energy and is requisite to better understand the pathway to more reproducible cold fusion (LANR) systems with higher incremental power gain. As a theoretical model, it has a few problems but they are very well defined.
 ISSN 2227-3123

Keywords: Zeroth Law, First Law, Second Law, Third Law, Calorimetry, Navier-Stokes, Bremsstrahlung, entropy

1.1 Introduction - Key to understanding Physical and LANR systems

Thermodynamics is the study of the relationships and conversions between heat and several types of energy: mechanical, electrical, radiant, nuclear, and chemical [1,2,3]. It is critical to understanding physical systems including lattice assisted nuclear reactions (LANR) systems. It also impacts and is the key to better understanding electrodes, diagnostics, and emissions.

Etymology - The word root 'thermo' derives from the ancient Greek word $\theta\acute{\varepsilon}\rho\mu\eta$ (pronounced 'therme') which means heat, and $\theta\varepsilon\rho\mu\acute{o}\varsigma$ (pronounced 'thermos') means hot, glowing, and boiling. The word root 'dynamics' shares use with dynamite and dynamo and dynamic [4]. "Dyne" comes from the Greek word dunamis [$\delta\acute{\upsilon}\nu\alpha\mu\iota\varsigma$] which means 'power' and was derived from the Greek translation of "koach" [כֹּחַ], the Hebrew word used in the Bible to describe the miraculous deliverance of Israel at the Sea of Reeds [Exodus 15.6]. The word 'energy', itself, comes from ancient Greek: $\grave{\varepsilon}\nu\acute{\varepsilon}\rho\gamma\varepsilon\iota\alpha$ (pronounced 'energeia') which means activity or a moving, working system. The word was used in Aristotle's writings, 2351 years ago. Aristotle wrote of two outcomes when dealing with energy:

> "there is some difference between ends: some ends are energeia [energy], while others are products which are additional to the energeia."

1.2 Problems of Thermodynamics

However, there are several problems with thermodynamics. The first one is that the actual origin of, and applications for, thermodynamics arise from observations and real complex systems involving matter and energy, and the analyses are really only close approximations. As discussed below, the second problem is that some of the "Laws" are not really Laws after all. Some are sometimes not even true, and one (the Third) is disproven by aqueous cold fusion (LANR)

 ISSN 2227-3123

systems. On the other hand, the first and second Thermodynamic Laws are linked fully both to our LANR systems and to all our measurements of their properties. In fact, from the measurements alone, thermodynamics is absolutely necessary, relevant, and critical for accurate energy accounting in experiments.

The bottom line is that one can better understand the scope, origin and applications of CF/LANR systems using these thermodynamic teachings. Therefore, the following review will discuss some of the origins and, most importantly, limitations.

2.1 Zeroth Law of Thermo - Required for "Temperature equilibration"

The Zeroth law of thermodynamics has been recently added to introduce the concept and property of matter known as "temperature equilibration", which is needed for the subsequent Laws. It simply states that at equilibrium, two objects touching will eventually achieve the same temperature.

3.1 First Law of Thermodynamics - Conservation of Energy

The first law of thermodynamics involves both the conservation of energy theorem and the requisite need to consider energy balance. The First Law's Origin begins with observations which were made by a physician looking at biological systems, then by an engineer trying to improve steam engines and finally by an electrochemist toiling in the laboratory. It was first elucidated and stated by Dr. Julius Robert Mayer (11/25/1814) [5,6]. During his teen age youth, as he grew up by a river in Germany, and tried repeatedly to use an Archimedean screw to pump water back up to the village homes. But, there was not enough energy for that.

In fact, as every experimenter before or since looking for 'excess energy' has found (except with CF/LANR), one cannot even recover the energy that is put in: there is no 'free energy'. This failure of repeated effort would come back later to make Dr. Mayer "discover" the First Law of Thermodynamics. Later, Mayer trained as a physician, at the Eberhard-Karls University graduating in May 1832. But Mayer and his friends (un)fortunately took a "wrong" political side in Europe in 1837 and exposed it openly by wearing forbidden colors ("couleurs"). He was arrested, found guilty, incarcerated, and Mayer was banished for one year. During this time, he voyaged to the Dutch East Indies where he practiced surgery/medicine aboard a Dutch ship. At the time, blood-letting was the state-of-the-art for many medical problems, and something caught Dr. Mayer's eyes. What he saw in the venous blood was very different in Jakarta compared to the color of the venous blood which he had seen in Paris. The color of his patients' venous blood was always darker in Europe than Jakarta. He reasoned that this was because less energy was exerted, and, therefore, less oxygen was extracted from the venous blood [5]. Therefore, there is less of an expected color change. This can be seen in Figure 4 where hemoglobin (encased in a polymer by the author) changes color as oxygen is removed; changing from orange-red to purple red [7,8]. Mayer therefore concluded that Europeans used more energy, extracting more oxygen. This energy control and conservation impregnated his thinking as had his failures with the Archimedes screw.

Soon thereafter, Julius Robert Mayer examined both energy and plants more closely. He noted that biological photosynthesis and oxidation as the primary sources of energy for living systems involved the plants converting light energy into chemical energy and work. He articulated the law of the conservation of energy, the First Law of Thermodynamics. In 1841, he wrote "On the Quantitative and Qualitative Determination of Forces" [9] and stated that "energy can be neither created nor destroyed". One of his first reviewer/referees, Tübingen physics professor Johann Gottlieb Nörremberg rejected Mayer's hypothesis and noted that if Mayer was right then kinetic energy, such as by vibration, would heat water. Mayer did that experiment, and showed by public demonstration these were connected. This paper was published in May 1842 in Annalen der Chemie und Pharmacie which have the value of the equivalent of heat very close to what is measured today [9]. Mayer was spot on. He then derived the relation between the specific heat at

Figure 1. A Classic Philosopher, a Physician, an Engineer, and an Electrochemist Deconvolved the "Laws" of Thermodynamics - (from left and clockwise): Aristotle, Dr. Julius Robert Mayer; Engineer Nicolas Léonard Sadi Carnot; Prof. Walther Nernst.

constant pressure and the specific heat at constant volume for an ideal gas. The relation is:

$$\mathrm{C_{P,m} - C_{V,m} = R} \tag{1}$$

where $C_{P,m}$ is the specific heat at constant pressure, $C_{V,m}$ is the specific heat at constant volume and R is the gas constant [10]. This important relation was needed to derive accurately the First Law. However, in response for his clear understanding and explanation of physics (while being a Doctor of Medicine, presumably), Mayer was viciously attacked by many including James Joule and Hermann Helmholtz.

This was shortly followed by attempted plagiarism of his idea by Joule, and finally acceptance of his idea by everyone [11]. Energy was conserved, and Mayer nailed its revelation and its understanding.

Standard Hemoglobin Optical Signatures - These are the colors, and the locations of the optical peaks of hemoglobin, and the optical signatures clearly showing the color change from increasing removal of ambient oxygen [7]. Shown are the optical signatures of d6electronic deoxy-hemoglobin (#1, pH 7.2), d6-oxyhemoglobin (#2, pH 7.2), and d5methemoclobin. Chemical reduction was achieved, and assayed by, sodium dithionite.

3.2 Definition of, and Origin of, the Concept of Energy

Now we must focus on an important, often ignored, matter. Exactly what is this thing called "energy", that is conserved. The origin, mathematically, of energy conservation is the homogeneity of time which requires that the Lagrangian in a closed system must not depend upon time. Therefore, when the time derivative is taken, with manipulation, a term -defined as the energy - remains a constant [12].

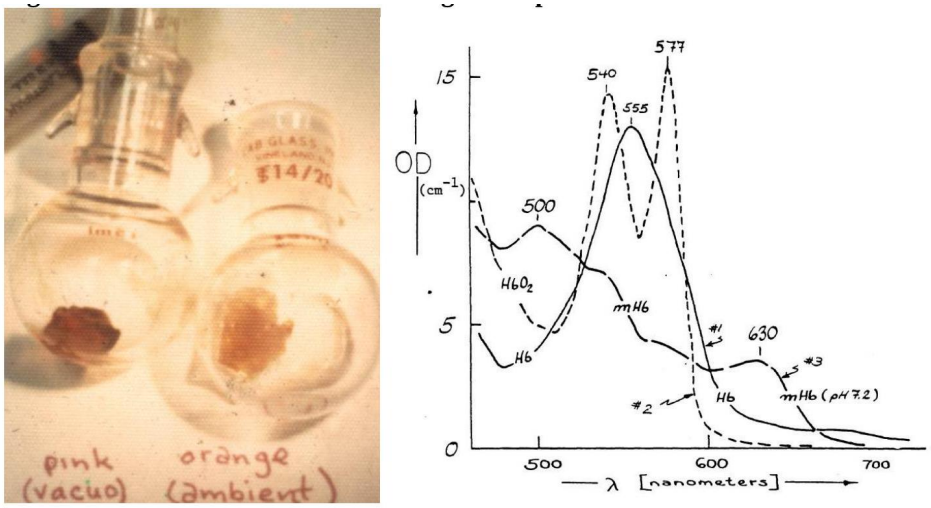

Figure 2. Colors of the Human Hemoglobin Species [after Swartz [ref. 7]]

Table 1. Colors of Hemoglobin (these are dependent on the oxygenation)

Species	Macroscopic color	Peak	Absorptions	[7,8]
deoxyhemoglobin	purple-red	429	555	650 nm
oxyhemoglobin	red-orange	413	540	577
carbonmonoxyhemoglobin	bright red	418	538	570
sulfhemoglobin	green	540	620	
methemoglobin -acid pH	brown	404	500	615
methemoglobin -neutral pH	brown	404	500	630
methemoglobin -alkaline pH	orange-brown	440	540	576 632
cyanmethemoglobin	yellow	418	541	

The relevant equations are thus, where E is the energy:

$$\frac{\mathrm{d}}{\mathrm{d}t}\left(\sum_i \dot{q}_i \frac{\partial L}{\partial \dot{q}_i} - L\right) = 0. \tag{2}$$

$$E \equiv \sum_i \dot{q}_i \frac{\partial L}{\partial \dot{q}_i} - L \tag{3}$$

In summary, what is taught today in elementary physics courses is conservation of energy -claimed by the First Law of Thermodynamics- and that means that energy can neither be created nor destroyed in a completely isolated system – but can only be changed to other forms. Therefore, as a corollary, the important notion of "energy balance" is also claimed by the First Law of Thermodynamics.

As Mayer noted, this relationship equalizes quantities, and their changes, in mechanical kinetic and potential energy systems, and chemical potential systems, and also their relationship to work. The First Law of Thermodynamics specifically states that the change in internal *energy* of a system is equal to the difference between the heat added to the system, the heat flow out through any barriers, and the work done by the system [1]. Some systems also have different

ways to do work including a mechanical spring, a pulley to raise a weight, or an electric motor. And the work may also include chemical reactions, loading palladium, magnetic strains in a material, and changes in surface energy. Thus, a more general form of energy balance includes the effects of heat transfer and internal energy changes. Therefore the relationship to CF also includes that we as scientists must actually use an even more general form which includes other forms of energy including electrostatic, magnetic, strain, and surface energy [13].

3.3 Classical Thermodynamic Equilibrium Parameters

Classically, thermodynamics is built upon knowledge of the equilibrium parameters involving temperature (T), pressure (P), volume (V), internal energy of the system (U), entropy (S), heat (Q) and work (W). They are related in several ways, and some combinations are important [1]. Most are known to all who studied physics. However, few actually are ever used for calculations, such as in calorimetry, electrochemistry, and electrical engineering. The Internal energy (U) is the kinetic energy of all of the molecules and electromagnetic energy in a system. Q is some of the internal energy which is involved in thermal energy transfer (heat).

The Enthalpy (H) is

$$\mathrm{H} = \mathrm{U} + \mathrm{P} * \mathrm{V} \tag{4}$$

The Gibbs Free Energy (G) is

$$\mathrm{G} = \mathrm{H} - \mathrm{TS} \tag{5}$$

The Helmholtz Free Energy is

$$\mathrm{A} = \mathrm{U} - \mathrm{TS} \tag{6}$$

which has “A” which is the work function (Arbeit means work in German).

Today, there are also non-Classical energy parameters. And one of the most important of these in LANR material science is the critical impact of phonons [4]. Some critics incorrectly purport without evidence that quasiparticles and coherent and collective excitations are not real. However, they are quite real and they actually produce many new properties of matter which are quite measurable, such as specific heat, as but one example. The heat capacity of a solid crystal has contributions to energy storage from the phonons, and the excitons, and the plasmons, proving they are quite real, and not imaginary. Furthermore, the phonons are associated with both the metallic lattice, $\mathrm{PdD_x}$, and the aqueous hydrogen lattice, $\mathrm{D_2O}$.

3.4 Energy Transport in Free Space, Vacuum, and Components

Energy can enter a system as work, as heat, and as electromagnetic radiation. The latter is described by the Poynting Vector [15,16,17]. Here, for simplicity and to first order, just the electrostatic contribution is considered. When electrically driving, either the CF/LANR component or system, and/or the ohmic control, both respond with an electrical current across them. As a result, when an electric current passes through an ohmic control (linear time-invariant heater) there is work being done.

With components, assume that the electrical current is constant, and that the component is homogeneous and isotropic so that Ohm’s law is present. Therefore, the electrical current depends upon the electrical conductivity and the applied electric field intensity.

$$\mathrm{J} = \sigma \mathrm{E} \tag{7}$$

The electrical current being constant means that the electric field intensity is constant, to the degree that there is minimal polarization, so that

$$\mathrm{curl}\, \mathrm{E} = 0 \tag{8}$$

It is also assumed that there is no charge buildup so that

$$\mathrm{div}\,\mathrm{J} = 0. \tag{9}$$

Hence, the E field intensity produces work by the E-field's interaction upon the charges. Therefore, the induced work dissipates power (work over time), and so, according to Joule's Law.

$$\text{Power dissipated } \mathrm{W} = \mathrm{J} * \mathrm{E} = \sigma * \mathrm{E}/2 \tag{10}$$

This is added to the Navier-Stokes equations by differential considerations, and this gives a differential amount of power, in the differential volume, predicated on the mass and specific heat capacity.

$$\mathrm{dW} = \mathrm{J} * \mathrm{EdV} \tag{11}$$

which in full form must be integrated over the volume, and over time. Many more complications arise from the lattice [18,19] and many are important to successful CF/LANR.

Energy and Power Losses in Hot and Cold Fusion Systems

As initially discussed by Prof. George Miley [20], power loss in fusion systems can involve other losses. The literature cites many components. Power loss from fusion systems ($\mathrm{P_{LOSS}}$) has the usual components of radiation ($\mathrm{P_{RAD}}$), conduction ($\mathrm{P_{COND}}$) and convection ($\mathrm{P_{CONv}}$). The power loss from radiation ($\mathrm{P_{RAD}}$) as usually considered in hot fusion systems to consist of radiation components secondary to Bremsstrahlung ($\mathrm{P_{BREM}}$), cyclotron radiation ($\mathrm{P_{CYC}}$), and optical emissions ($\mathrm{P_{OP}}$). Furthermore, in cold fusion systems, these must augmented by three additional terms, which represent additional effects of conduction and convection. As George Miley has shown these include blackbody power emission ($\mathrm{P_{BB}}$), heat (enthalpy) conduction ($\mathrm{P_{ENTH}}$), and the power loss which results through the exit gas stream ($\mathrm{P_{GAS}}$).

The heat conduction in hot fusion is usually handled through its implicit incorporation in the energy confinement time. Here, in LANR, it is included explicitly in equation 1 because the excess enthalpy of cold fusion is the major signal of the desired reactions where phonons play a significant role in hyrided lattices and their electronic behavior.

$$\mathrm{P}_{LOSS} = \mathrm{P}_{RAD} + \mathrm{P}_{COND} + \mathrm{P}_{CONVECT} = \mathrm{P}_{BREM} + \mathrm{P}_{CYC} + \mathrm{P}_{OP} + \mathrm{P}_{BB} + \mathrm{P}_{ENTH} + \mathrm{P}_{GAS} \tag{12}$$

3.5 Bremsstrahlung in Fusion Systems

Bremsstrahlung [13, 21, 22] is most important to LANR since 1989 especially given the alleged 'graduate student problem' [23]. Bremsstrahlung radiant power from cold fusion differs from hot fusion in being markedly lower in intensity, with an output spectrum in the near infra-red. In hot fusion, significant levels of Bremsstrahlung occur at hot temperatures characteristic of plasmas. Because of the energies involved, the Bremsstrahlung radiation is penetrating and cannot be contained.

This is important because at relativistic energies, the energy loss by Bremsstrahlung may exceed that secondary to all collision interactions with matter surrounding and within the reactor. In hot fusion systems, the energetic ions and electrons of the plasma radiate so much ionizing (x-ray) power by Bremsstrahlung that this radiation leakage challenges reactor planning. To explain this much more clearly, the following goes into this physics in detail.

Bremsstrahlung [Breaking Radiation]

Bremsstrahlung, described by a theoretical energy spectrum and angular distribution [22,23], has an observed power output spectrum as a function of the emitted photon energy. The output spectral curves are continuous, and also

contain characteristic material-specific photon peaks (lines) superimposed. The latter occurs from the displacement of lower-lying electrons in the target and the subsequent refilling of those orbitals.

There are two well-known types of Bremsstrahlung - outer and inner. Outer Bremsstrahlung is the release of ionizing radiant energy from highly energetic moving charged particles upon their deceleration [20,21]. This form of Bremsstrahlung was first observed when it produced secondary x-radiation from fast moving electrons hitting thick metallic targets. Inner Bremsstrahlung occurs in β-decay and results in the emission of photons in energy between zero and the maximum energy available for that transition. Inner Bremsstrahlung, double Bremsstrahlung [26]–[28], polarization Bremsstrahlung, solar Bremsstrahlung [29] and the relativistic Bremsstrahlung associated with hadronic showers including solutions by the Weizsacker-Williams method of virtual quanta will not be discussed in this paper.

Bremsstrahlung Radiation Cross section

The energy in the Bremsstrahlung output spectrum is expressed for incident beam or gendanken experiments as a cross section of photon emission [13]. This enables the determination of the beam energy loss as a function of distance [$\frac{dErad}{dx}$]. The radiation cross section of Bremsstrahlung has been considered several ways including classical, semiclassical quantum, and the Bethe-Heitler quantum mechanical Born approximation (done in 1934). Calculations usually begin with the kinetic energy of the moving particle considered, relativistically if necessary [30, 16, 31]. The emission of Bremsstrahlung radiation is most important for low mass (m) particles impinging upon high atomic number materials ($\mathrm{Z_M}$), and therefore for electrons impinging upon palladium ($\mathrm{Z} = 46$) or nickel ($\mathrm{Z} = 28$).

If N is the number of fixed charges in a unit thickness, the energy loss per unit distance becomes

$$\frac{dE\,\mathrm{rad}}{dx} = \mathrm{N}\int \chi(\omega)d\omega \tag{13}$$

Equation 13 is solved by use of conversion to a new variable of integration, $x = \geq \frac{h\omega}{2\pi E}$. The radiative loss per unit distance by Bremsstrahlung is thus

$$\begin{aligned}\frac{dE\,\mathrm{rad}}{dx} &\cong \frac{16}{3}N * \left(\frac{2\pi Z_M^2 e^2}{hc}\right) * \left(\frac{z^4 e^4}{Mc^2}\right)\\ &= [32/3] * N * \pi * \left[\mathrm{Z_M}^2\right] * \left[\mathrm{e}^6/\mathrm{hc}^3\right] * [\mathrm{z4/M}]\\ &= \frac{32}{3}N\pi Z_{\mathrm{M}}^2 \frac{\mathrm{e}^6}{\mathrm{hc}^3}\frac{\mathrm{z}^4}{\mathrm{M}}\end{aligned} \tag{14}$$

Screening Effects for sufficient relativistic energies

Screening effects due to the target atomic electrons have not been considered above, but are typically included through their relationship to the impact parameter [13]. There is a critical energy ($\mathrm{E_S}$) beyond which the impinging relativistic particles are said thereafter to have "complete" screening. The important result from screening considerations, discussed elsewhere, is that for all $\mathrm{E} > \mathrm{Es}$, the Bremsstrahlung radiation cross section changes and, thereafter for increasing frequencies, becomes constant. Where does this occur for the materials used in cold fusion? For beam systems where this has been experimentally confirmed, for electrons in aluminum ($\mathrm{Z} = 13$) this critical energy, $\mathrm{E_s}$, is about $\sim 42\mathrm{MeV}$, and for lead ($\mathrm{Z} = 82$), the relevant relativistic energy $\mathrm{E_s}$ is $\sim 23\mathrm{MeV}$. This is characterized by

$$\mathrm{E}_s = \left(\frac{192\mathrm{M}}{z_M^{\frac{1}{3}}\,\mathrm{m}}\right)\mathrm{Mc}^2 \tag{15}$$

Equation 15 was used to calculate the expected critical energy ($\mathrm{E_s}$) for the hydrided materials associated with cold fusion. For electrons in palladium ($Z = 46$), this calculation is $\mathrm{E_s} =\sim 28\mathrm{MeV}$. For nickel ($\mathrm{Z} = 28$), it $\mathrm{E_s} \sim 33\mathrm{MeV}$, and titanium ($\mathrm{Z} = 22$), $\mathrm{E_s} \sim 35\mathrm{MeV}$. The important relevant conclusion is that the Bremsstrahlung screening effect is unimportant in this analysis of cold fusion systems.

Calculation of λ_{min}

By inspection, conservation of energy requires that the maximum wavelength of Bremsstrahlung emission be limited to, under non-relativistic conditions, the kinetic energy of the incident particle, and so $\frac{hc}{\lambda_{\mathrm{min}}} \cong \frac{1}{2}\mathbf{M v}^2$. This has great impact upon radiation behavior[13]. The upper limit for photon energy emission occurs at the shortest wavelength [Angstroms] which is inversely dependent upon the voltage (V) used.

$$\lambda_{\mathrm{min}} = \frac{hc}{eV} = \frac{12,396}{V} \tag{16}$$

The Bremsstrahlung of cold fusion differs from hot fusion due to the lower temperature. At cold fusion temperatures, circa 300 K implying equivalent energies of $1/40$ electron volt, the maximum energy (minimum wavelength) output of Bremsstrahlung emission is in the near infra-red. Given this result, the most important implication is that cold fusion Bremsstrahlung would have insignificant penetration of the electrode or even aqueous medium. The penetration depth, and its implications, will be calculated after first considering the relative role of Bremsstrahlung radiation to all collision related energy losses.

Final Bremsstrahlung Output Power Calculation

The standard calculation for plasma and hot fusion Bremsstrahlung requires determinations of both ion density and excitation energy [13,32]. The Bremsstrahlung power equation becomes

$$\mathrm{P_{BR}} = 5.35 \times 10^{-31} \mathrm{f} \sum_j k_j \mathrm{Z}_j^2 * \left(\mathrm{n}^2\right) * \ \mathrm{T}^{e\frac{1}{2}} \tag{17}$$

where $\mathrm{f} = \sum_j k_j * Z_j$ the electron temperature is $\mathrm{T_e}$ (in keV), and there are n ions/cm^3, containing j nuclear species, of charge Z_j and of fraction density (sum $= 1$) of $\mathrm{k_j} * \mathrm{n}$. Here, Z is the nuclear charge, $\mathrm{n_i}$ and $\mathrm{n_e}$ are ion and electron densities (number of particles $/\mathrm{cm}^3$) and T is the electron temperature $[\mathrm{keV}]$.

Important Metric of Radiant X-ray Power

First, the Bremsstrahlung radiant x-ray power volume is much less at cold fusion (CF) temperatures (~ 300 K) than at thermonuclear temperatures. However, the determination as to whether Bremsstrahlung is important for CF (as it is for thermonuclear fusion) also depends upon the ratio of Bremsstrahlung power to fusion power. In kinetic beam experiments as discussed above, it is also important to consider the radiant x-ray power in comparison to input electrical beam power. In the sense that cold fusion experiments also have central electrical input power distributions as the etiology of the fusion mechanism, this factor was also examined for the case of cold fusion.

$$\eta = \frac{x\text{-ray power}}{\text{beam power}} = 0.0007 * \mathrm{Z} * \ \mathrm{V} \tag{18}$$

The ratio of x-ray power to beam power falls from 0.05–0.28 (hot fusion, characterized by aluminum and lead targets, Table 1) to $1.4 - 8.1 \times 10^{-10}$ for cold fusion [palladium $\mathrm{Z} = 42$, and water (average $\mathrm{Z} = 8$)]. This marked decrease in the exit of ionizing Bremsstrahlung radiation is directly reflected in the irradiation dose delivered. This

can be calculated [13] from the x-ray beam dose equation [32], here modified as the x-ray dose in Grays (at 1 meter) delivered per coulomb of electrical input.

$$\mathrm{D/Q} = 1.50 * \ \mathrm{V_{max}}^{2.8*}\mathrm{Z}^{1/2} \text{ [Grays/Coulomb]} \tag{19}$$

$\mathrm{V_{max}}$ here is dominated by $\mathrm{k_B T}$ because the applied electrical field intensity, assuming homogeneous distribution over the system is insignificant by comparison. This most important result from equations 18 and 19 is the correct calculation that the derived value of the Bremsstrahlung delivered dose at a distance of 1 meter is some 11 to 18 orders of magnitude less than that expected for conventional fusion systems.

> Most importantly, the irradiation dose (Grays) per coulomb at 1 meter drops from 3.1×10^{19} Grays (hot fusion) to 1.4-3.3 $\times 10^{-4}$ Grays for cold fusion [13].
>
> [embolden for emphasis below it.]

This result is consistent with experimental findings over more than three decades. Again there is no reason for the experimenters in cold fusion laboratories to have easily seen any ionizing radiation because, like neutrons, there are theoretical reasons for x-radiation to be absent. Some recent experiments are consistent with cold fusion (using the codepositional method) producing very low levels of ionizing energy release in the range of $\sim$ 6 to 30 keV [33,35]; and for emissions from NANOR-type components [34,36].

3.5.2 Implication of Shift to Nonionizing IR Output

We have closely examined the impact of the fact that Bremsstrahlung radiant power exists, in cold fusion systems, in the near-infrared [13]. The shift of the cold fusion Bremsstrahlung output power spectrum to non-penetrating radiant energies has great implications. The first implication of the maximum energy with cold fusion is the increase in the role of self-attenuation. As an example of how significant this effect might be, consider that small amount of even low-Z filtration produces the well-known effects of beam hardening widely used by radiologists for a century. For example, when 65 keV electrons are bombarded into tungsten targets, the filtering of 1 mm aluminum alone cause all radiation below about 10 keV to drop to virtually zero.

The second implication is effective containment of the radiant Bremsstrahlung power, and its overlap with thermal and phonon processes[13]. With cold fusion, could the impact of this present serious and interesting physics because of the extremely limited skin depth? It must be true that the final boundary condition will be the StefanBoltzmann distribution of blackbody radiation characterizing the system.

However, in this case, there is the additional, albeit small, localized input from the cold fusion Bremsstrahlung radiation which may act to supplement the local phonon field.

IMPACT OF SKIN DEPTH

The loss of potential fusion energy through Bremsstrahlung radiation is very low for cold fusion systems because the radiation is in the near infrared and, therefore, is trapped by the skin depth effect to remain vicinal to the reactions[13]. The infrared radiation is essentially locked into the materials, as opposed to the penetrating, uncontained, ionizing radiation of hot fusion. The energy transfer in cold fusion through Bremsstrahlung is limited by the skin depth which is relatively small. The skin depth is defined, in continuum terms, where σ is the conductivity, and μ the permeability, by

$$\delta_{\text{skindepth}} = \frac{2}{\sqrt{\omega * \mu * \sigma}} \tag{20}$$

For palladium (9.25×10^6 mhos/meter), at 1 Megahertz this is 0.066 mm , but in the infrared [$10^{13} - 6 \times 10^{14}$ Hz], the skin depth ranges from 2.7 to 20.9 nanometers. This must be compared to the hot fusion Bremsstrahlung which is very penetrating with tenth value thicknesses of lead ranging from 0.2 to 65 millimeters.

The result of equation 20 is that because of the skin depth, the energy of the Bremsstrahlung radiation is trapped inside the metal, possibly in thermodynamic equilibrium, and can only exit by blackbody radiation, exit gas stream (or possibly monatomic gases, or ions, through catastrophic desorption) or further phonon conduction.

Possible Secondary Effects

Most importantly, the lock-in effect means that there may be additional post-fusion contributions to the optical and acoustic phonons. These lattice vibrations have coupling in the infrared, which itself is linked with molecular vibrations. Given the lattice, additional phonons would thereafter develop. To the degree that these phonons are needed to continue further CF reactions, the cold fusion Bremsstrahlung might accelerate the desired reactions.

3.5.3 Summary Analysis of Bremsstrahlung

It is important to summarize these very important results.

We have examined the role of Bremsstrahlung in cold fusion systems [13]. The results show why those figurative cold fusion graduate students never died, unlike hot fusion or plasma systems. The reason the graduate students, and CF/LANR researchers were saved. The reason why is that we calculate that there is a VERY marked shift in Bremsstrahlung power density compared to beam power, from 0.05-0.28 (hot fusion) to $1.4 - 8.1 \times 10^{-10}$ for cold fusion [palladium $Z = 42$, and water (average $Z = 8$)].

As a result, the delivered x-ray beam dose (at 1 meter) decreases by 11 to 18 orders of magnitude as the irradiation dose (Grays) per coulomb drops from 3.1×10^{19} Grays (hot fusion) to 1.4-3.3 $\times 10^{-4}$ Grays for cold fusion.

Attention is directed to the fact that these calculations, based upon temperature, are consistent with the relative absence of apparent ionizing emissions from cold fusion systems except for a few reports looking in the ~ 6 to 20 keV region.

Most importantly, the Bremsstrahlung radiant power from cold fusion differs from hot fusion in that - because of the markedly lower temperature - most of the Bremsstrahlung radiant power in cold fusion systems is in the near-infrared region.

This occurs because the energy transfer in cold fusion systems via Bremsstrahlung radiation is limited by the skin depth which for palladium ($9.2510^6 \mathrm{mhos}/$ meter), in the near infrared [$10^{13} - 6 \times 10^{14}$ Hz] ranges from 2.7 to 20.9 nanometers. This is important because the lock-in of cold fusion Bremsstrahlung has important secondary effects upon the rates of the desired fusion reactions. One very important implication for CF/LANR is that the effective containment of the radiant Bremsstrahlung power, and its overlap with thermal and phonon processes [37-39].

3.6.1 Application of First Law: Energy Conservation in Calorimetry

Now we come to the role of energy conservation in calorimetry. Until the development of LANR detection systems like coherent antiStokes CMORE spectroscopy [37-3] and Deuterium-line RF emissions [40–42], CF/LANR investigators have had to rely solely upon calorimetry (and occasional mass spectroscopy when very lucky to look for de novo $^4\mathrm{He}$). Calorimetry will remain the mainstay for a long while.

In calorimetry, there are several important types [43–50]. When pressure remains constant, it is an isobaric process. When temperature remains constant, it is an isothermal process. When there is no exchange of heat between the gas and the environment, it is an adiabatic process. More commonly in this field, there is a constant volume while the pressure is free to change. This is an isovolumetric or isochoric process.

An isoperibolic system is a system in which the controlling external temperature is kept constant.

Calorimetry by Conservation of Energy and Mass

For analysis, for each type we must consider the specific heat of water, and use NavierStokes analysis to examine the flow of matter and energy [50]. Another advantage of using this method is that it is valid always. By contrast, the Nernst equation is not even valid unless there is equilibrium which is why the very successful quasi-1-dimensional model of loading was developed [14].

3.6.2 Derivation of Navier-Stokes Equation

The Navier-Stokes equation is derived from $\mathrm{F} = \mathrm{ma}$, which is conservation of momentum and from the equations for conservation of mass and energy. Conservation of mass requires the continuity equation [50].

- Conservation of momentum

$$m\vec{a} = \sum \vec{F} \tag{21}$$

mass; acceleration; Sum of all forces acting on fluid

- Conservation of mass (continuity equation)

$$\nabla \cdot \vec{\imath} = 0 \tag{22}$$

- Conservation of Energy

$$\rho c \frac{\partial T}{\partial t} = k\nabla^2 T + \dot{q} \tag{23}$$

Rate of change of local heat energy stored; heat conducted out; heat generated

Navier Stokes equation

$$\rho[\frac{\partial V}{\partial t} + (V.\nabla)V] = \rho\frac{D\vec{V}}{Dt} = -\nabla p + \rho\vec{g} + \mu\nabla^2\vec{V} \tag{24}$$

Convective derivative; Convective derivative; Pressure; Gravity; Diffusion

The increment in internal energy (enthalpy) per unit mass is $c_\nu dT$ for an ideal gas where c_ν is the specific heat at constant volume. $c_p dT$ is the incremental change in enthalpy per unit mass at constant pressure.

The desired equations add the forces on the right-hand side of Equation 24, here being force(s) which arise from a pressure gradient, from gravity, and diffusion. Finally, because this is a Euler equation (a flow though a volume) rather than a Lagrangian [such as where the ball is thrown, as a $f(x, y, z)$], the convective derivative is needed and used on the left-hand side of Eq. 24 .

3.6.3 Benard Instability, and the Boussinesq Approximation

In some cases of flow calorimetry, the thermal expansion of the involved fluids must next be addressed. The key problem is that water and air and other fluids used in flow calorimetry suffer from thermal expansion. Their density is

a function of temperature. Thus, water when it freezes floats on top, as one example, thereby fortunately saving all of the life below in the pond during the Winter.

For simplicity, the Boussinesq approximation is used, which only considers the thermal expansion in any term of Eq. 4 involving gravity (such as on the right hand side). Solution leads to Benard instability, the Rayleigh Taylor wavelength, and what is universally observed in continuum electromechanics [51]. This equation is generally ignored in simplistic flow calorimetric systems/calculations.

η_B Evaluates Impact of Buoyancy Effect

We derived a non-dimensional number $(= \eta_B)$ which can determine if flow calorimetry is defective when it is significantly greater than zero, and can be used to correct the flow calorimetry to the first order [52-56].

η_B is the ratio of heat transported by the buoyant forces to the heat transported by the applied solution convection.

η_{B} is also derivable from other non-dimensional factors including the Archimedes non-dimensional number (which is the ratio of the buoyant force to the viscous force), and the Rayleigh non-dimensional number (which is the ratio of gravity to thermal conductivity).

3.6.4 First Order Correction for Buoyancy Factor

To zeroth order one can write using the specific heat capacity, the temperature differential, and the rate of mass transfer caused by both the expected convection and the buoyancy movement secondary to the temperature inhomogeneity [56].

$$P_{\text{observed}} = P_{\text{out}} + P_{\text{error}} = C_p * \Delta T * V_{\text{total}} \cong C_p * \Delta T * (V_{\text{convection}} + V_{\text{buoyancy}}) \tag{25}$$

The chain rule in calculus and consideration of coolant redistribution reveal the higher order terms from the impact of the buoyant flow.

$$\frac{\delta P_{\text{error}}}{\delta \eta_B} = (C_p * \Delta T * V_{\text{convection}}) + \left(C_p * V_{\text{convection}} * \eta_B * \frac{\delta \Delta T}{\delta \eta_B} \right) \tag{26}$$

The term containing $\frac{\delta \Delta \mathbf{T}}{\delta \eta_{\mathrm{B}}}$ depends upon many factors including the total tank volume just outside the reactor (or thermal control) and the actual input temperature boundary condition. However, that term appears to be higher order, and so the linear correction to the observed power becomes

$$P_{\text{corrected}} = P_{\text{observed}} - (C_p * \Delta T * V_{\text{convection}} * \eta_B) \tag{27}$$

An improved estimate of the purported gain (or over-unity gain) then becomes, corrected to first order [56],

$$P_{\text{corrected}} = P_{\text{observed}} * (1 - \eta_B) \tag{28}$$

This important result means that the semiquantitative corrected Incremental Power Gain of these experiments is equal to the indicated Incremental Power Gain times $(1 - \eta_B)$.

3.7 Limitation of the First Law

That said, there are limitations of First Law. They are VERY important for cold fusion by any name (CF/LANR/LENR). First, the First law cannot even indicate if a reaction(s) is spontaneous, or its rate, or the direction of heat or deuteron flow, nor will it provide information about final temperatures or concentrations or distributions, or information on the entropy. Electrical engineering of applied fields and Navier-Stokes models with convective derivatives are far more useful.

Second, in addition, the first law of thermodynamics cannot determine or distinguish which direction heat flows between a cold object and a hot object. Yet we observe the heat flows in one direction only - heat only flows from a hot body to a cold body.

4.1 Second Law of Thermodynamics - Entropy Always Increases

The Second Law of Thermodynamics declares that entropy will always increase, which for most things of large number is quite reasonable [1]. Entropy is a thermodynamic parameter, symbol S, describing disorder in a system or in a material. Entropy is disorder but it heralds more. The availability and accessibility of energy depends on entropy. It is more difficult to access energy as the entropy increases. The origin, limitations, and other issues of the Second Law are described in detail below.

The change in entropy during a thermodynamic process is defined as:

$$\Delta S = \int \mathrm{dQ/T} \tag{29}$$

Thus, going back to electrical heating, the total entropy increase is defined as

$$\mathrm{dS/dt} = \int \left(J^{*}\mathrm{E}\right)/\mathrm{T}\ \mathrm{dV} \tag{30}$$

4.2 Origin of the Second Law of Thermodynamics

The Second Law of Thermodynamics was derived by the French physicist Nicolas Léonard Sadi Carnot in 1824 [57]. He was a French engineer trained at the École Polytechnique in Paris by Joseph Louis Gay-Lussac, and André-Marie AmpÃÍre. His classmates were Claude-Louis Navier and Gaspard-Gustave Coriolis, and with them Carnot studied steam engines. Carnot died of cholera at 36, and his writings were buried alongside him.

In those days, heat was viewed as an invisible flowing liquid. In 1824, Carnot published Reflections on the Motive Power of Fire [58, 59] postulating the Carnot cycle and first discussed the idea of "reversibility" where work would give a temperature rise. Carnot's work showed there are losses in work, from entropy, and only its absence yielded the upper limit of efficiency of converting heat to work [60–63]. He demonstrated that the maximum thermal efficiency of a heat engine occurred when all the heat supplied was at a constant temperature (T1), and when all the work was conducted at a constant temperature (T2). The maximum thermal efficiency was related to both and is

$$\eta_{\max} = 1 - \left(\left(\mathrm{T}_1\right) * \left(\ \mathrm{T}_2\right)\right) \tag{31}$$

This is an alternate equation from the second law of thermodynamics. The equation was very useful since the efficiency of steam engines was 3%.

4.3 Limitation of the Second Law

The Second Law of Thermodynamics is not a "Law" as much as it is a statement of probability. The Second Law of Thermodynamics purports that the state of entropy of an isolated system will increase over time, but there are many limits to it. Two examples are shown below.

First, entropy involves large numbers of particles/systems, so this cannot refer to Lagrangian single particle. Cohorts must be used, resulting in probabilities. Thus, sometime small numbers of particles can break the Second Law, but large numbers make breaking the Second "law" extremely unlikely.

Second, another weakness of the "law", is that the Second Law states that the time rate of change of the entropy can never be negative over the Universe, but locally, over a small volume, biology, and artificial intelligence and advanced materials demonstrate that THAT "law" may not be always true.

4.5 Entropy in Language [Including Discussions of CMNS]

Entropy from the Second Law is relevant to CF/LANR even when we and our colleagues speak about it. This is why: Entropy is the metric used to measure uncertainty in both physics and in languages ("communication"). In the latter, entropy refers to the amount of randomness of speech or text, and failure to communicate.

To understand this quantitatively, consider that the goal of any language is to transmit information. The amount of information in a message is denoted by the "entropy", as proposed by Claude Shannon [64,65]:

> "The entropy is a statistical parameter which measures, in a certain sense, how much information is produced on the average for each letter of a text in the language."
> ["Prediction and Entropy of Printed English"].

Shannon's entropy is a measure of uncertainty. The higher the entropy, the more frequent are communication errors. This is how it is related to speech and text. Language performance is measured by perplexity, cross entropy, and bits-per-character (BPC), and accuracy. Perplexity reflects the uncertainty. Perplexity as metric shows if a probability distribution or probability model actually will predict an accurate result. The actual crossentropy is greater than the calculated entropy because it involves an additional loss from coding and/or recognition for logistic regressions and artificial neural networks.

Bits-per-character and bits-per-word are the metrics used which enable determination of Shannon's definition of entropy. Entropy is also directly proportional, to first order, to the maximum attainable data speed transmission rate [in bps (bits per second)]. Entropy is also the average number of binary digits required per letter of the original language to translate each letter in a most efficient way.

> "If the language is translated into binary digits (0 or 1) in the most efficient way, the entropy is the average number of binary digits required per letter of the original language."
> ["Prediction and Entropy of Printed English"].

The entropy of a language is an estimation of the probabilistic information content of each letter in that language and so is also a measure of its predictability and redundancy. Entropy of a language thus becomes a statistical parameter which measures, in a certain sense, how much information is produced on the average for each letter of a text in a language. In language, some words always are linked with others, and this effects the entropy. This additional relationship/linkage is important because the probability is linked to the preceding word/symbol.

5.1 The Third Law of Thermodynamics

The Third Law of Thermodynamics was formulated by the German chemist Walther Nernst in 1906 [66-69]. The Third Law of Thermodynamics purports that the entropy of a system approaches a constant value as the temperature approaches absolute zero, and that value for all perfectly crystalline solids is zero at the absolute zero temperature ["perfect order in a crystalline solid"].

Many problems in electrochemistry and CF/LANR in particular have arisen from the Nernst equation. These have been discussed by Herbert Uhlig [70], and there are major differences with other electrochemists who relied only on the Nernst equations [70,71]. The issues are beyond this paper and have been covered elsewhere [14]. The most important point is that these things are known and the Nernst equation is only relevant at equilibrium whereas active CF/LANR systems and components are definitely not at equilibrium [14].

5.2 Limitation of the Third Law

There are limitations of Third Law of Thermodynamics. They may be important for cold fusion. Several things do not fit this including glassy solids, mixtures of isotopes of a single element, and some simple molecules including CO, N_2O, NO, H_2O, and probably heavy water. Each has an entropy greater than zero at absolute zero. This will be shown by way of water, and heavy water. Water is described here because of its entropy, and how it demonstrates that the Third "Law" fails. First, a thermodynamic review of water, and its lattices [72,73].

5.2 Water - Critical to LANR and many Calorimeters

Water has a great heat capacity with a negligible increase in temperature [72]. It is the deuterogen bonds, and the diversity of structures available to water, which accounts for this important phenomenon [72-78]. High boiling point is another corollary. The origin of the heat capacity is the entropy discussed below.

There are Two Lattices in Water and Ice

Water has a three dimensional stereoconstellation, and surprisingly it has both order (the oxygen atoms) and disorder (the protons or deuterons) [73]. Water's atoms of oxygen and hydrogen (or deuterons) are arranged in structures with definite physical rules and it is best understood as a complicated three-dimensional structure comprised of two lattices. The lattice of the protons and/or deuterons is located within a second lattice (the oxygen atoms). The most important point is that there are two lattices and that the proton lattice is often totally ignored. Much has been learned by studying the protons, their electric dipole moments, and their entropy, which results from their distribution and decoration upon the organized oxygen lattice [73].

The fact that water has a second proton lattice within it means that water has not only singular properties, but has an incredible impact upon both the properties of materials dissolved within it (including clathrates, hydrates, biological systems, etc.) and the operation of systems using it. Additional complexities occur because the hydrogen in water could be the rarer heavy hydrogen, deuterium, which is the desired fuel in CF/LANR and is used at 99 to 99.95% purity levels in the best CF/LANR systems.

Hydrogen/Deuteron Bond

The immersion of a hydrogen, actually the proton, into an electronic cloud of a neighboring water molecule begins the process toward understanding water/ ice structure. The H -bond process consists of that immersion of one proton into the electronic cloud of a neighboring oxygen acceptor. A wide range of angles are possible for the lone electron-pair acceptor. The coulombic neutralization yields an energy decrease in the order of $4.5\mathrm{kcal/mole}\,(\mathrm{k_BT} = 0.6\mathrm{kcal/mole})$. What occurs when the hydrogen bond is formed is that a thermally-stable structure results and an electric dipole moment is formed [72-76]. The bridge dipole is a simplification, because it is actually a superposition of individual dipole moments. Each bridge consists of two dipoles. The vector sum can be associated with each bridge.

The deuteron bond, similar to the "hydrogen bonds" of light water, decisively controls this materials aggregation properties. This occurs because of the ratio of the energy involved in a deuterogen bond (~ 4.5 kilocalories per mole) versus the lesser, albeit omnipresent, thermal energy $[\mathrm{k_BT}]$ which is only 0.6 kilocalories per mole. The result is that thermal energy $[\mathrm{k_BT}]$ is insufficient to disrupt more than a statistically few deuterogen bonds at any given time [73].

5.3 Deuteron/Proton Disorder in the Condensed Phase

The oxygen lattice is strictly ordered, but it is important to know that the proton sublattice is disordered. The proton disorder of water's hydrogen sublattice leads to the unusual electric conduction and polarization properties of water.

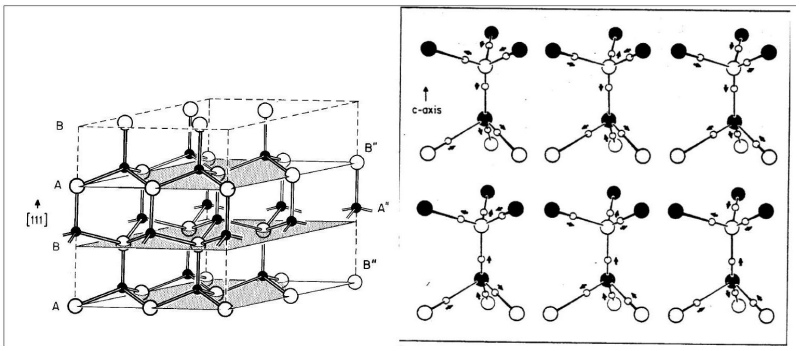

Figure 3. (left) Ordinary ice (Ice lh) lattice showing the oxygen nuclei in hexagonal arrangement. The Wurtzite-type structure of Ice 1 h showing the lattice which creates an open optical (c-axis) axis, viewed best using crossed polarizers, consisting of tetrahedral H_2O molecules held in a proton-disorder stereoconstellation [72–78]. Contained within the ordered oxygen tetrahedral lattice is the disordered proton sublattice. The disordered results from the fact that every oxygen bridge has two (2) nearly equivalent proton positions. (right) Possible arrangements of protons in water. Shown are the six possible arrangements of protons in a Wurtzite-like (eclipsed) Ice 1h structure composed of eight water molecules.

Most importantly, the proton disorder creates the large dielectric constant of water that enables water to dissolve so many materials. Furthermore, the proton disorder of water/ice contributes to the great heat capacity of water {the ability to absorb heat with a negligible increase in temperature}.

Figure 3 shows 6 possible configurations which can exist for two oxygen nuclei. Because these are indistinguishable, there are only 3 such configurations [72,73-75]. Furthermore because each layer eliminates randomness from the next layer there are $3/2 = 1.5$ arrangements. The calculated entropy, therefore is

$$\mathrm{S} = \mathrm{k_B} * \ln \text{ (Number of states)} \tag{32}$$

Examining the form of ice, thus the entropy S is:

$$\mathrm{S} = \mathrm{R} * \ln(1.5) = .81$$

Note that this calculated value is indeed very close to the measured value of .82 calories/gram-mole.

This entropy for water-ice, calculated here to high accuracy, does not follow the Third "Law" at absolute zero temperature, but lessons remain none-the-less.

6. Conclusion

Thermodynamics is our best, constantly developing, engineering method to study the inter-relationships and multiple (re)-conversions between heat and several types of energy; both in the world around us, and in the local version within our CF/LANR experiments. Thermodynamics is fundamental, but as shown here, it must be tempered and considered alongside both actual engineering and material science realities. Together, their science is the proven way to excellently understand it better toward our goal(s) of achieving better working, more reproducible cold fusion (LANR) systems with higher incremental power gain and power density.

In lattice assisted nuclear reactions (LANR) systems, thermodynamics controls electrodes, explains diagnostics, and limits emissions. Although thermodynamics has several problems, as all limited first-order guess-work analyses do, they are now very well defined, and therefore, discussing its scope, its origins, and its many roles in our measurements will continue to improve the development and engineering of CF/LANR systems.

Acknowledgments

The author gratefully acknowledges, and thanks, for their helpful comments, editorial assistance, ideas, suggestions, and much long term support for this effort: Gayle Verner, Jean-Paul Biberian, and his reviewers, Alex Frank, Joshua Gyllinsky, Susan Woods, Thomas Farina, Michael Staker, John Wallace, Andrew Meulenberg, Brian Josephson, Isidor Straus, Peter Hagelstein, Dennis Cravens, Dennis Letts, Frank Gordon, Pamela Mosier-Boss, Lawrence Forsley, Brian Ahern, Jeff Driscoll, Raymond Kurwzeil, Aaron Kleiner, Christy Frazier, Win Cuthbert. This effort was supported by JET Energy Inc. NANOR® and PHUSOR® are registered trademarks. The technology described here is protected by patents pending.

References

[1] Frederick Reif, Fundamentals of Statistical and Thermal Physics, ISBN-10: 9781577666127, Waveland Pr Inc; (2008)
[2] Richard P. Feynman, Robert B. Leighton, Matthew Sands, The Feynman Lectures on Physics, Vol. I: Mainly Mechanics, Radiation, and Heat; ISBN-10: 8131792110 (2011)
[3] Prigogine, Ilya, Introduction to Thermodynamics of Irreversible Processes, New York: Interscience Publishers (John Wiley & Sons), 1968; https://isidore.co/calibre#panel=book_details&book_id=4305
[4] Swartz, M. R, Quasiparticles, Collective Excitations and Higher-Order Collective Quasi-Excitations in Lattice Assisted Nuclear Reactions, J. Condensed Matter Nucl. Sci. with Excess Heat Mode, J. Condensed Matter Nucl. Sci. 24, 130-145 (2017)
[5] Julius von Mayer: https://en.wikipedia.org/wiki/Julius_von_Mayer
[6] Michael Fowler, Robert Mayer and the Color of Blood, https://galileo.phys.virginia.edu/classes/152.mf1i.spring02/MayerJoule.htm
[7] Swartz M.R., "Charge Transfer to Methemoglobin and Oxygen using Methylene Blue, Light and Electricity", ScD Thesis, Dept. of Electrical Engineering, MIT, Cambridge, MA, (1984).
[8] van Assendelft, O. W. "Spectrophotometry of the Hemoglobin Derivatives", Royal Vangoricum Ltd., Netherlands (1970).
[9] J. R. von Mayer, Annalen der Chemie und Pharmacie 43, 233 (1842); Mayer, J. R. (1842). "Bemerkungen Ãijber die KrÃd'fte der unbelebten Natur". Annalen der Chemie und Pharmacie. 42 (2): 233-240. doi:10.1002/jlac. 18420420212. hdl:2027/umn.319510020751527; Mayer, J R (1862). "Remarks on the Forces of Inorganic Nature". Philosophical Magazine. 4. 24 (162): 371-377. doi:10.1080/14786446208643372.
[10] Lehninger, A. "Biochemistry", Worth Inc. New York (1975)
[11] Esther Inglis-Arkell, Why Julius Robert von Mayer was one of the unluckiest men in science, 2013; https://gizmodo.com/why-julius-robert-von-mayer-was-one-of-the-unluckiest-m-5985512
[12] L.D. Landau & E.M. Lifshitz Mechanics (Volume 1 of A Course of Theoretical Physics) Pergamon Press 1969; https://archive.org/details/Mechanics_541
[13] Swartz, M, G. Verner, "Bremsstrahlung in Hot and Cold Fusion", J. New Energy, 3, 4, 90-101 (1999)
[14] Swartz, M, "Quasi-One-Dimensional Model of Electrochemical Loading of Isotopic Fuel into a Metal", Fusion Technology, 22, 2, 296-300 (1992)
[15] Von Hippel, A. Ed., "Dielectric Materials and Applications", MIT Press, Cambridge (1954).
[16] Adler, R.B., L. J. Chu, R.M. Fano, "Electromagnetic Energy Transmission and Radiation", Wiley & Sons, Inc., NY (1966)
[17] Melcher, J. R., "Continuum Electromechanics", MIT Press, Cambridge, (1981).
[18] Kittel, C., Introduction to Solid State Physics, 8th Edition, ISBN:978-0-471-4152688th Edition (2004)
[19] Ashcroft, Neil W., N. David Mermin, Solid State Physics, ISBN-13: 978-0030839931, Publisher Brooks Cole (1976)
[20] Miley, G.H., "Fusion Energy Conversion", American Nuclear Society (1976)
[21] Kaplan, Irving, "Nuclear Physics", Addison-Wesley Publishing, Reading MA (1962); Johns, H.E., Cunningham, "The Physics of Radiology", Charles C. Thomas Publisher, Springfield, 1953.
[22] Friedlander, M. W., "Cosmic Rays", University Press, Cambridge MA (1989)
[23] Mallove, E. J. (1999). Fire from Ice: Searching for the Truth Behind the Cold Fusion Furor, Infinite Energy Press, United States of America, ISBN 1-892925-02-8; Eugene F. Mallove (1991), Fire from Ice: Searching for the Truth Behind the Cold Fusion Furor, Wiley Science Editions (illustrated ed.), John Wiley & Sons, ISBN 978-0-471-53139-5

[24] L.I. Schiff, Phys. Rev. 83.2, 252 (1951)
[25] J. L. Matthews and R. O. Owens, N.I.M. 157-168 (1973)
[26] C. Quarles, J. Liu "Review of Two-photon Bremsstrahlung in Electron-atom Collisions," Nucl. Inst. Meth. Phys. Res. B, 79, 142 (1993).
[27] C. Quarles, J. Liu, "The yield for two-photon emission from radiation of thick targets by a Cd109-Cd113m radioactive source", Nucl. Inst.Meth. Phys. Res. A., 337, 127 (1993).
[28] C. A. Quarles, D. Kahler and J. Liu, "Double Bremsstrahlung", Phys. Rev. Letters, 68, 1690 (1992).
[29] Friedlander, M. W., "Cosmic Rays", University Press, Cambridge MA (1989)
[30] Heitler, W., "The Quantum Theory of Radiation", Oxford Clarendon Press (1954)
[31] Jackson, J.D., "Classical Electrodynamics", Wiley & Sons, Inc., NY (1962)
[32] Huba, J.D., NRL Plasma Formulary, Office Naval Research (1994)
[33] S.Szpak, P. Mosier-Boss, R. Boss, J. Smith, "On the behavior of the Pd/D system: Evidence for Tritium Production", Fusion Technology (1998)
[34] Swartz M. R., Incremental High Energy Emission from a $ZrO_2 - PdD$ Nanostructured Quantum Electronic Component CF/LANR, J. Condensed Matter Nucl. Sci. 15, 92 (2015);
[35] Swartz, M.R., "Survey of the Observed Excess Energy and Emissions In Lattice Assisted Nuclear Reactions", Journal of Scientific Exploration, 23, 4, (2009) 419-436.
[36] Swartz M.R., Verner, G., et al., Imaging of an Active NANORÂő-type LANR Component using CR-39, J. Condensed Matter Nucl. Sci. 15, p 81 (2015);
[37] Swartz, M. R, Peter L. Hagelstein, Increased PdD anti-Stokes Peaks are Correlated with Excess Heat Mode, J. Condensed Matter Nucl. Sci. 24, 130-145 (2017)
[38] Swartz, M. R, Increase of an Anti-Stokes Peak at the Cathode of an ElectricallyDriven, Active Aqueous Nickel/H2O/Pt System, J. Condensed Matter Nucl. Sci., Vol 279, 22 (2018)
[39] Swartz, M.R. "Optical Detection of Phonon Gain Distinguishes an Active Cold Fusion/LANR Component", JCMNS, 20, 29-53 (2016)
[40] Swartz, M. R, Active LANR Systems Emit a 327.37 MHz Maser Line, Proc. ICCF-22, J. Condensed Matter Nucl. Sci., Volume 33, pages 80-110 (2020)
[41] Swartz, M. R, FCC Vacancies in ZrO2PdD RF are the Active LANR Site, Proc. ICCF-22, J. Cond.Matter Nucl. Sci., Volume 33, pages 126-144 (2020)
[42] Swartz, M. R, Pulsatile Superhyperfine Lines at 327.37 MHz Herald LANR Activity and Possible Mass-Energy Transfer, Proc. ICCF-22, J. Condensed Matter Nucl. Sci. , Volume 33, pages 111-125 (2020)
[43] Fleischmann M., S. Pons, "Electrochemically Induced Nuclear Fusion of Deuterium", J. Electroanal. Chem., 261 [erratum, 263, 187] (1989) 301-308
[44] Fleischmann M., S. Pons, "Some comments on the paper Analysis of Experiments on Calorimetry of LiOD/D $_2$O Electrochemical Cells, R.H.Wilson et al., J. Electroanal. Chem., 332 (1992) 1* ", J. Electroanal. Chem., 332, (1992) 33-53
[45] Fleischmann M., S. Pons, M. Anderson, L.J. Li, M. Hawkins, "Calorimetry of the palladium-deuterium-heavy water System", Electroanal. Chem., 287, (1990) 293
[46] Fleischmann M., S. Pons, "Calorimetry of the Pd-D2O system: from simplicity via complications to simplicity", Physics Letters A, 176, (1993) 118-129
[47] McKubre MCH, Crouch-Baker S, Rocha-Filho RC, Smedley SI, Tanzella FL, Passell TO, Santucci J, "Isothermal flow calorimetric investigations of the DlPd and H/Pd systems", J. Electroanal. Chern. 368 (1994) 55.
[48] Cravens, Dennis, "Flowing Electrolyte Calorimetry", Proceedings of 5th International Conference on Cold Fusion, 79-86 (1995).
[49] Swartz M. Thermal Conduction and Non-Differential Temperature Corrections to the Enthalpic Flow Equation, J. New Energy 3, No. 1, (1998), p 10-13; www.iscmns.org/FIC/J/JNE3N1.pdf
[50] Melcher, James "Continuum Electromechanics," MIT Press, Cambridge, 10. 13-10. 18 (1981). https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=4&cad=rja&uact=8&ved=2ahUKEwj8pc7XrIjjAhVorlkKHfQjBI4QFjADegQIBhAC&url=https%3A%2F%2Focw.mit.edu%2Fans7870%2Fresources%2Fmelcher%2Fresized%2Fcem_811.pdf&usg=AOvVaw1ityC4BWlIPTM792pP5DX7

[51] Chandrasekhar, S, "Hydrodynamic and Hydromagnetic Stability," Clarendon Press. Oxford, 9-75 (1961).
[52] Swartz, M. R., "Potential for Positional Variation in Flow Calorimetric Systems", Journal of New Energy, 1, 1, 126-129 (1996) http://world.std.com/˜mica/Swartz_Calib-ErrorsbyVerticalFLow(1996).pdf
[53] Swartz, M. R., "Heat Transported by Buoyant force May Augment solution convection in Flow calorimetric systems", "Sixth International Conference on Cold Fusion", October 1996, Toya, Hokkaido, Japan (1996). http://world.std.com/˜mica/Swartz_Calib-HeatBouyantForce.pdf
[54] Swartz, M. R., "Linear Correction for Heat Transport Secondary to Buoyant Forces in Flow Calorimetric Calculations", (1996). http://world.std.com/˜mica/Swartz-Calib-LinearCorrxn(1996).pdf
[55] Swartz, M. R., "Improved Calculations Involving Energy Release Using a Buoyancy Transport Correction", Journal of New Energy, 1, 3, 219-221 (1996). http://world.std.com/˜mica/Swartz-Calib-ImprovCalc(1996).pdf
[56] Swartz, M. R, Buoyant Heat Transport in Flow Calorimetry, Proc. ICCF-22, J. Condensed Matter Nucl. Sci., Volume 33, pages (2020); [18] Jacques Ruer, Basics of air flow calorimetry, paper n58, 22nd International Conference for Condensed Matter Nuclear Science ICCF-22 (2019).
[57] Nicolas Léonard Sadi Carnot; https://en.wikipedia.org/wiki/Nicolas_Léonard_Sadi_Carnot
[58] Carnot, Sadi (1977), Mendoza, E. (ed.), Reflection on the Motive Power of Fire and other papers translated into English, Gloucester, Massachusetts Peter Smith Wilson, S.S.(August 1981), "Sadi Carnot", Scientific American, 245 (2): 102-114, 1981 doi:10.1038/scientificamerican0881-134
[59] June 12, 1824: Sadi Carnot publishes treatise on heat engines, This Month in Physics History, APS News, June 2009 (Volume 18, Number 6) https://www.aps.org/publications/apsnews/200906/physicshistory.cfm
[60] S A Ulybin, The founder of the theory of heat : Bicentenary of S Carnot's birth (Russian), Vestnik Ross. Akad. Nauk 66 (6) (1996), 518-521.
[61] F Sebastiani, The caloric theories of Laplace, Poisson, Sadi Carnot and Clapeyron, and the theory of thermal phenomena in gases formulated by Clausius in 1850 (Italian), Physis-Riv. Internaz. Storia Sci. 23 (3) (1981), 397-438.
[62] T.S.Kuhn, Engineering precedent for the work of Sadi Carnot, Archives internationales d'histoire des sciences 13 (1960), 251-255.
[63] Harald Sack, Nicolas Léonard Sadi Carnot (1796-1832), physics 1, June 2020 http://scihi.org/carnot-thermodynamics/
[64] C. E. Shannon, "Prediction and Entropy of Printed English," Bell Systems Technical Journal, 30, 1951 pp. 50-64. www.ics.uci.edu/˜fowlkes/class/cs177/shannon_51.pdf.
[65] Evaluation Metrics for Language Modeling 18.Oct. 2019 file:///C:/Users/Public/Documents/Evaluation%20Metrics %20for%20Language%20Mod eling.htm
[66] Walther Nernst, Walther Hermann Nernst; https://www.britannica.com/biography/Walther-Nernst https://en.wikipedia.org/wiki/Walther_Nernst; Walther Nernst;
[67] Cherwell, F. Simon (1942). "Walther Nernst, 1864-1941". Obit. Note. Fell. R. Soc. Lond. 4 (11): 1022.
[68] Mendelssohn, Kurt Alfred Georg (1973), The World of Walther Nernst: The Rise and Fall of German Science. London: Macmillan. ISBN 978-0-333-14895-2; Mendelssohn, K. (1973), The World of Walther Nernst, University of Pittsburgh Press. p. 39. ISBN 978-0-8229-1109-8;
[69] Barkan, Diana Kormos (1998). Walther Nernst and the Transition to Modern Physical Science. Cambridge: Cambridge University Press. ISBN 978-0-521-44456-9.
[70] H. H. Uhlig, "Corrosion and Corrosion Control", Wiley (1971).
[71] J. O'M Bockris, A. K. N. Reddy, "Modern Electrochemistry", Plenum Press (1970).
[72] Swartz, M. R, Water Is Best, Infinite Energy, 134, pp 16-29, July/August (2017)
[73] Swartz. M., "Dances with Protons - Ferroelectric Inscriptions in Water/Ice Relevant to Cold Fusion and Some Energy Systems", Infinite Energy, 44, (2002).
[74] von Hippel, A., Knoll, D.B., and Westphal, W.B. 1971. "Transfer of Protons Through 'Pure' Ice 1h Single Crystals," J. Chem. Phys., 54, 134.
[75] von Hippel,A. and Farrell, E.E 1973. Mat. Res. Bull., 8,127. von Hippel, A. "Molecular Mechanisms of Conduction and Polarization in Water Vapor, Liquid Water, and Ice, MIT 1972-1973.
[76] von Hippel, A. 1971. J Chem. Phys., 54, 145.
[77] Bjerrum, N. 1951. Kgl. Danske Videnskab. Selskab., Fys. Medd., 27,1.
[78] Bjerrum, N. 1951. Dansk. Mat.-Fys. Medd., 27, 32. Bjerrum, N. 1951. Dansk. Mat.Fys. Medd., 27, 41.