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The Strong Force is Magnetic.

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After one century, the underlying fundamental laws of nuclear physics are still missing. The only presently recognized electromagnetic interaction in a nucleus is the so-called Coulomb force, repulsive. Chadwick assumed an attractive strong force to equilibrate the Coulomb repulsive force. Bieler assumed it to be magnetic, attractive, instead of being repulsive, thus missing the discovery. Indeed, it needs only, at high kinetic energies, above the Rutherford singularity, to reuse the Rutherford formula where the repulsive electric -2 exponent is replaced by the also repulsive magnetic -6 exponent. This is consistent with the electromagnetic nature of the nuclear binding energy (B. Schaeffer, Electromagnetic Theory of the Binding Energy of the Hydrogen Isotopes, Journal of Fusion Energy, 30:377-381, 2011). Nuclear scattering and binding energy are both electromagnetic: no need of a hypothetical strong force.

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1. Introduction

Two proofs the electromagnetic nature of the nuclear interaction have been obtained:

1 - The Rutherford scattering is well known to be electric. At high kinetic energies, the so-called anomalous scattering has been discovered to be magnetic. The electric exponent -2, at low kinetic energies, is replaced by the magnetic exponent -6 at high kinetic energies. The Rutherford scattering is thus entirely and only electromagnetic.

2 -The binding energy of nuclei has also been calculated successfully, without fit, by the bare application of the electromagnetic theory. Indeed, there is an electric attraction between a proton and a not so neutral neutron equilibrated by their magnetic repulsion [1,2].

2. Rutherford Anomalous Scattering

Alpha particles, from a radioactive source, striking a thin gold foil produce a tiny, but visible flash of light when they strike a fluorescent screen (Fig. 1). Surprisingly, α particles were found at large deflection angles and, unexpectedly, some of the particles were backscattered [3].

With a fixed given angle, alpha particles from a nuclear source are projected into a detector. At high kinetic energies, the α particles are lightly deviated by gold foils. At low energies they are strongly deviated. Rutherford developed the electric scattering formula relating the cross-section and the kinetic energy of the α particles. He explained why some alpha particles projected on an atom were reflected by a small nucleus: ”Assuming classical trajectories for the scattered alpha particles, Coulomb’s law was found to hold for encounters between alpha particles and nuclei" [4]. The first evidence of departures from Coulomb’s law other than those in α scattering by H and He was observed by Bieler [5].

The Rutherford singularity appears at kinetic energies approaching the α particle binding energy, in absolute value, 28 MeV. For kinetic energies larger than 28 MeV [7], the relative cross section decreases anomalously faster than predicted by the electric Rutherford formula (Fig. 2). Magnetic interpretations have been tempted without success [5,8], due to the wrong sign assumed for the magnetic moment.

The hypothetical strong force cannot be used: its fundamental laws are unknown. The purpose of this paper is to solve the problem of the not so anomalous scattering of α particles.

(a) Nuclear Interaction Theories

Rutherford discovered that the impacting electrically charged α particles are deviated by the **repulsive** electrostatic Coulomb force of the impacted nuclei. The origin of the concept of strong force comes from the observation of the discrepancy between Rutherford theory and experiment at high kinetic energies (fig. 2). Up to now no theory with only fundamental laws and constants was able to explain quantitatively the nuclear scattering at kinetic energies larger than 28 MeV, the total binding energy of the α particle.

(i) Strong Force Theory

Geiger [3] observed that the deviation was larger than predicted by the electric force. Chadwick and Bieler determined that an attractive force, distinct from the electromagnetism [9–12], of very great intensity holds the nuclei together in the nucleus.

Even after one century of nuclear physics, the myth of the strong force remains. This force, assumed to be distinct from the electromagnetism, is usually assumed to be 137 times more powerful than the electromagnetic interaction [10] (no proof found). "It is natural to assume that for smaller distances the force becomes **attractive**" [13]. Sexl [14] and Houtermans [15] discussed, for the potential formula, different exponents **n**, from **2** to **4**. The electric potential was **repulsive**

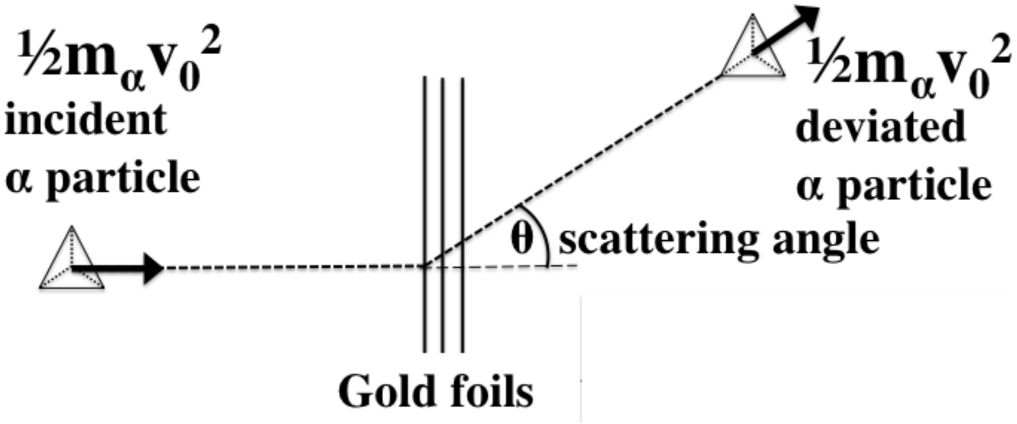

Figure 1. Rutherford experiment - The α particles are emitted by radium, impacting thin gold, lead or other metal foils. The α particles are scattered all around, even backwards, astonishing Rutherford [3–5,9]. We are here only interested by the variation of the cross section σ as a function of the kinetic energy. The kinetic energy is defined by the number, thickness, scattering angle, nature of the metal foils. The differential cross-section is the microscope hole surface $d\sigma$ divided by the corresponding solid angle $d\Omega$: $\frac{d\sigma}{d\Omega}$. The fixed scattering angle $\theta = 60^0$ is a constant, only the kinetic energy varies.

and the "strong force", **attractive** [9]:

$$V(r) = +\frac{2Ze^2}{4\pi\epsilon_0 r} - \frac{B}{r^{\mathbf{n}}}\ (\mathbf{n} > \mathbf{1}) \tag{2.1}$$

The first term in equation 2.1 corresponds to the electric Rutherford scattering and the second term to the so-called "anomalous scattering", magnetic if **n = 3**. The sign of B [16], not specified, seems to be positive.

(ii) Electromagnetic Theory

The electromagnetic theory is based on Coulomb [17] and Poisson [18] potentials. Bieler hypothesized the existence of **attractive** magnetic moments, thus with **n = 3** for the potential [5,6,9]:

$$V(r) = +\frac{2Ze^2}{4\pi\epsilon_0 r} - \frac{2Z|\mu_0\mu_n\mu_p|}{4\pi r^3} \tag{2.2}$$

N.B. Bieler uses the force instead of the potential, thus the "Inverse Fourth Power Law" [5,6].

Nuclear scattering became entirely and only electromagnetic. Unfortunately, with the **attractive** negative sign of the magnetic potential, Bieler was unable to solve the problem [5,6] although it needed only to change the sign of the magnetic term. Indeed, by replacing the **attractive** negative sign of the Bieler magnetic interaction by a **repulsive** positive sign with also **n = 3**, the potential becomes:

$$V(r) = +\frac{2Ze^2}{4\pi\epsilon_0 r} + \frac{2Z|\mu_0\mu_n\mu_p|}{4\pi r^3} \tag{2.3}$$

At low kinetic energies, r being large, we have the electric Rutherford formula with a $1/r$ potential. At high kinetic energies, the α particles approaching more to the nucleus, r becomes small, the magnetic $1/r^3$ potential increases and dominates the electric potential, becoming the main component of the complete potential. It seems also that the α particles are destroyed as suggested by the observation that the sum of the α particle binding energy and of the kinetic energy approaches zero at the Rutherford singularity. Eisberg and Porter [7] obtained precise experimental results (fig. 2), better seen on figure 3, proving that the Rutherford scattering is electric at kinetic energies lower than 28 MeV and magnetic at high kinetic energies from 28

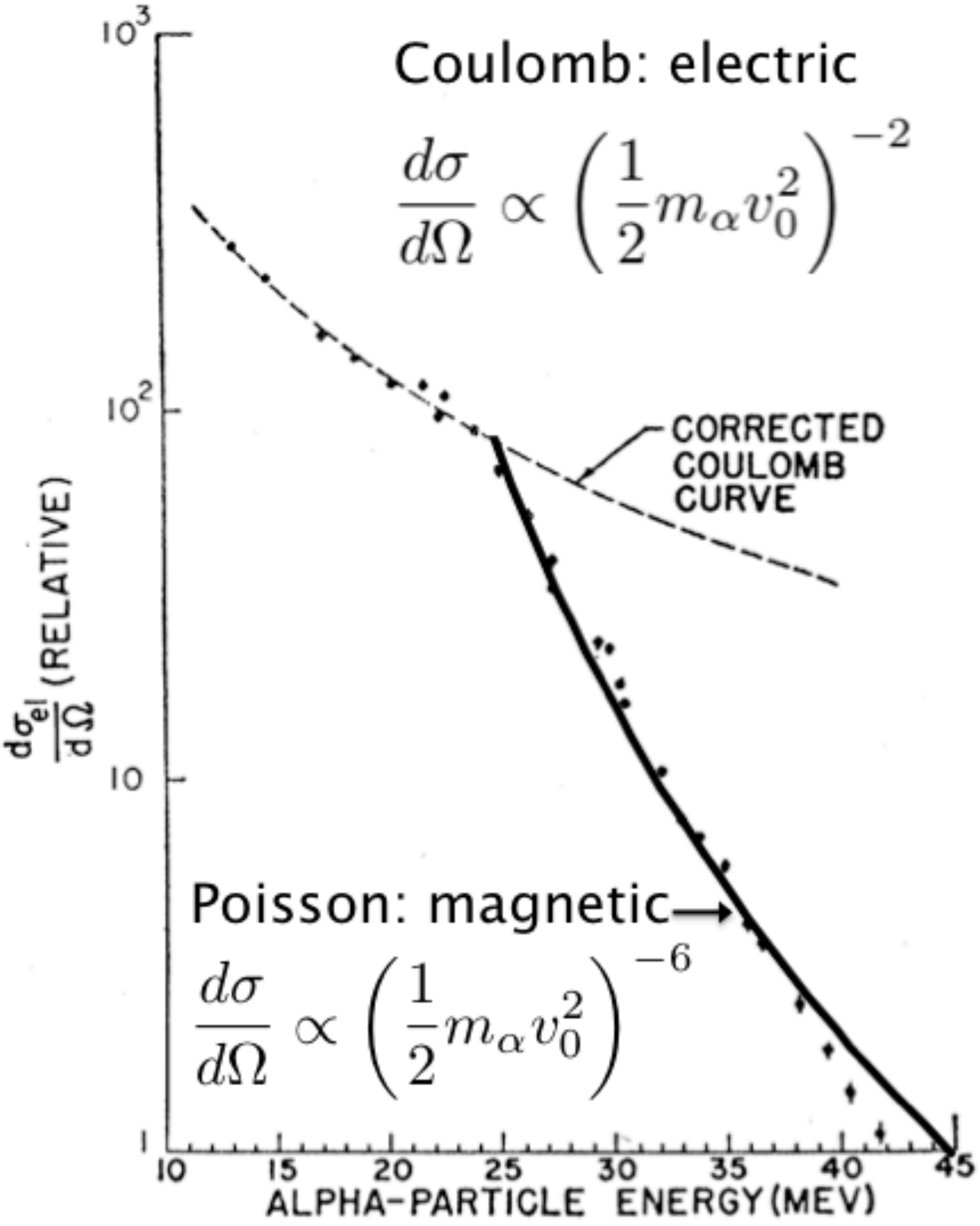

Figure 2. Rutherford scattering at low Coulomb [17] kinetic energy and high Poisson [18] kinetic energy - This figure shows the experimental points [7] with the electrically and magnetically calculated curves. The relative differential cross section $\frac{d\sigma}{d\Omega}$ is a targeted area per solid angle per unit time. The α particles are projected on Ta foils at a fixed scattering angle $\theta = 60^0$ with initial kinetic energies varying between 13 and 42 MeV [7]. The α particles are repulsed and deviated by the Ta nucleus Coulomb electric force in the direction of the particle exit trajectory (Fig. 1). The inverse electric potential energy coincides with the experimental points of the original figure, used as background. The Rutherford singularity appears at kinetic energies approaching $28\ MeV$ able to dismantle the α particles, having a binding energy of $-28\ MeV$. At higher kinetic energies, the curve deviates, due to a hypothetical attractive "strong force" [9]. Bieler [5] assumed unfortunately an **attractive** magnetic force [9] assumed to equilibrate the **repulsive** electric force. In this paper, it is discovered that the Poisson magnetic force is **repulsive** as the electric Coulomb force. The Rutherford formula works fine, even for the not so anomalous scattering, provided that the electric $-$**2** be replaced by the magnetic $-$**6**. On figure 3 one obtains two straight lines with slopes $-$**2** and $-$**6**.

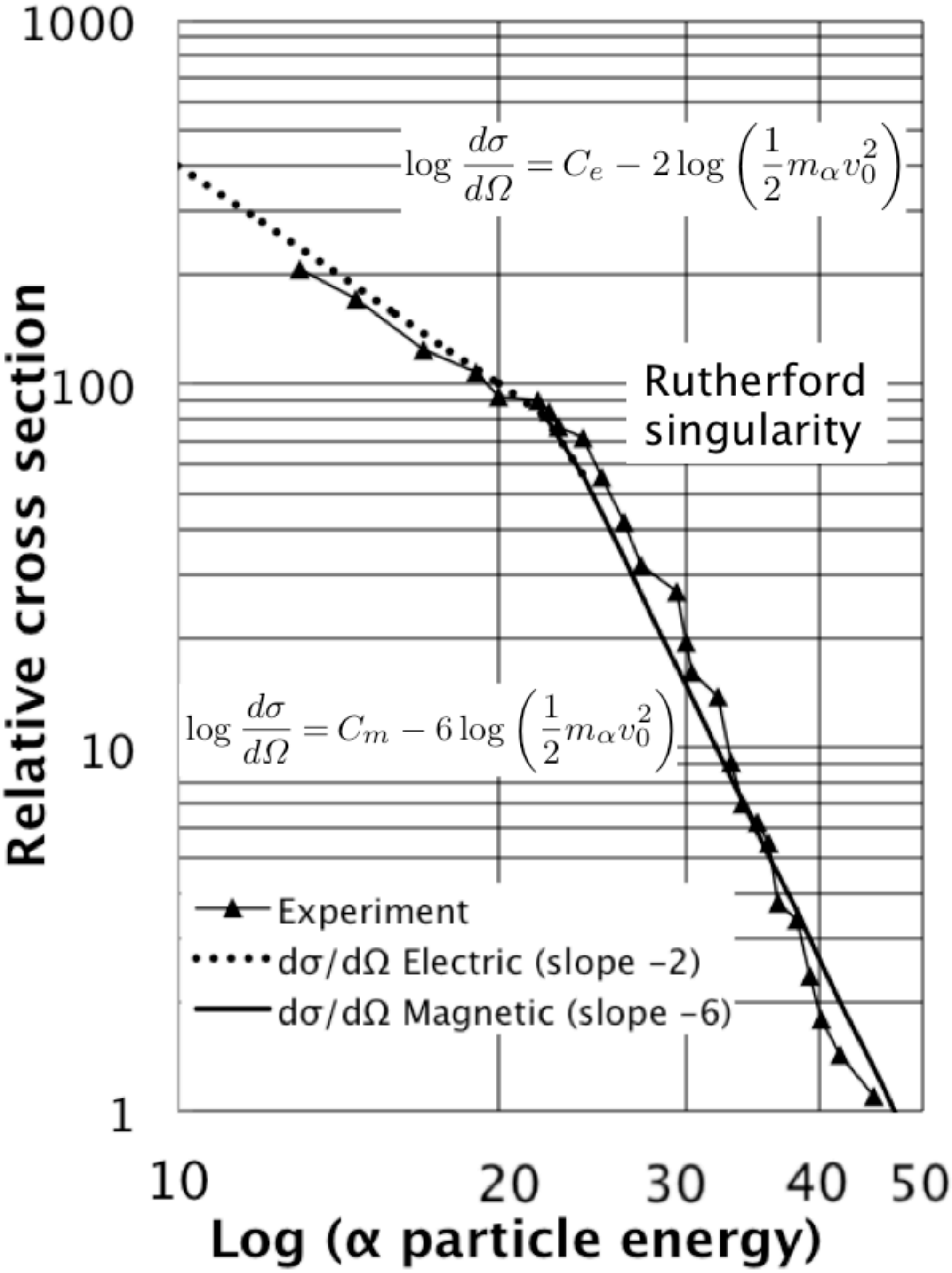

Figure 3. Coulomb [17] and Poisson [18] scattering in log-log coordinates - In contrast with semi-logarithmic coordinates (Fig. 2), the log-log coordinates give straight lines with slopes $-\mathbf{2}$ and $-\mathbf{6}$ corresponding to the electric $1/r$ and magnetic $1/r^{\mathbf{3}}$ potentials. They cross at the Rutherford singularity. C_e and C_m are constants adjusted to the singularity, not yet calculated.

MeV to 40 MeV. This is perfectly consistent with both the electric Rutherford scattering and the electromagnetic theory of the nuclear binding energy [1,2].

Practically, due to the singularity, we may separate the electric and magnetic interactions, thus giving two straight lines with a slope of $-\mathbf{2}$ for the electric interaction and $-\mathbf{6}$ for the magnetic interaction (fig. 3).

(iii) Differential cross-section

The differential cross-section $\frac{d\sigma}{d\Omega}$ is defined as the ratio of the number of particles scattered into a constant direction θ, per unit time and per unit solid angle $d\Omega$. The complete Rutherford formula, where one may see the singularity at $\theta = 0$ is:

$$\frac{d\sigma}{d\Omega} = \left(\frac{1}{4\sin^2\frac{\theta}{2}} \times \frac{zZe^2}{4\pi\epsilon_0} \times \frac{1}{\frac{1}{2}m_\alpha v_0^2}\right)^2 \tag{2.4}$$

For a given angle θ, the so-called differential cross-section $\frac{d\sigma}{d\Omega}$, only relatively known, the Rutherford formula may be simplified into:

$$\frac{d\sigma}{d\Omega} = C_e \left(\frac{1}{2}m_\alpha v_0^2\right)^{-2} \tag{2.5}$$

where m_α is the mass of ${}^4He$, the impacting nucleus. v_0 is the velocity, constant By conservation energy the energy and velocity v_0 of the outgoing scattered αparticle is the same as that with which it began. The exponent $-\mathbf{2}$, due to the electrostatic interaction cross-section, becomes, logarithmically, the coefficient $-\mathbf{2}$:

$$\log\frac{d\sigma}{d\Omega} = \log(C_e) - \mathbf{2}\log\left(\frac{1}{2}m_\alpha v_0^2\right) \tag{2.6}$$

where C_e is to be adjusted to the singularity, provisionally only experimentally defined. The log-log graph shows straight lines on Fig. 3. Same thing for the Poisson magnetic formula [18], except that the exponent of the Rutherford formula is replaced by $-\mathbf{6}$ instead of $-\mathbf{2}$ (Eq. 2.6). C_e is replaced by C_m:

$$\log\frac{d\sigma}{d\Omega} = \log(C_m) - \mathbf{6}\log\left(\frac{1}{2}m_\alpha v_0^2\right) \tag{2.7}$$

The variables are the differential cross section $\frac{d\sigma}{d\Omega}$ and the initial α particle velocity v_0. The constants C_e and C_m are provisionally adjusted to make coincide the intersection between the electric and magnetic straight lines near the Rutherford singularity, 25 MeV on Fig. 3, near to the opposite of the ${}^4He$ binding energy. At the singularity, the initial kinetic energy is more or less lower than the absolute value of the α particle total binding energy, $|-28|$ MeV (Fig. 3).

We have now one formula for electric scattering (eq. 2.6) and another one for magnetic scattering (eq. 2.7). The difference between "normal" and "anomalous" scattering is the potential exponent, $-\mathbf{3}$ for the magnetic potential instead of $-\mathbf{1}$ for the electric interaction. The slopes are $-\mathbf{6}$ and $-\mathbf{2}$ due to the cross sections in a log-log graph.

The kinetic energy at the Rutherford singularity is less than the experimental value of the total binding energy of the α particle, $|-28|$ MeV (Fig. 2, 3, 4), probably (only few experimental results available) decreasing inversely with the impacted nucleus mass.

(b) Discussion

Rutherford discovered the electric part of the nuclear interaction. The repulsion between protons was improperly called "Coulomb force", although the electrostatic force may be **attractive** or **repulsive** as between a proton and a neutron, ignored in mainstream nuclear physics. Chadwick [9] choose an **attractive** force interacting indistinctly between nucleons (NN). Bieler assumed it to be magnetic and also **attractive** [5]. He was thus unable to solve the problem of the high energy scattering. As far as I know, nobody tried a magnetic **repulsive** force.

At short r, the **repulsive** magnetic potential in r^{-3} overcomes the also **repulsive** electric potential in r^{-1}. No need of an **attractive** hypothetical "strong force". More precise results, theoretical and experimental, taking into account second order electromagnetic interactions, should be explored with light and heavy nuclides. Quantum mechanics and/or relativity, are not needed, at least for kinetic energies between 10 and 50 MeV.

(c) Conclusion

As the Rutherford model, one century ago, overturned Thomson's plum-pudding model, the magnetic interaction overturns Chadwick's strong force hypothesis. Bieler had almost solved the problem magnetically: unfortunately, the sign was wrong. In log-log coordinates, it suffices to replace the $-\mathbf{2}$ of the Rutherford electric formula by the $-\mathbf{6}$, magnetic, to obtain two straight lines coinciding respectively with the electric and magnetic scattering curves (figure 3). The Rutherford scattering is electric at low energy and magnetic at high energy, **both repulsive**. Except for the position of the singularity, there is no fit, only fundamental laws and constants.

Nuclear scattering is electric at low energies and magnetic at high energies. Nuclear binding energy is essentially the static equilibrium between electric attraction and magnetic repulsion between a proton and a not so neutral neutron [1,2]. The nuclear interaction is electromagnetic: no need of a new type of force.

3. Acknowledgements

Thanks to persons at Dubna for their interest to my electromagnetic theory of the nuclear energy. The first question was about scattering. I said I don't know. Now I know: the anomalous Rutherford scattering is magnetic. The second question was: *"The strong force doesn't exist?"* and a third one about orbiting nucleons [19].

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