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# The Quantum-Mechanical Explanation of the Thermal Radiative Behaviour of Helium (Sequal)

**Thomas Allmendinger**

Glattbrugg, Switzerland
Email: inventor@sunrise.ch

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## Abstract

In a recently published paper the thermal radiative behaviour of Helium, which had been reported already in 2016, was quantum-mechanically explained using a planar atom model with well-defined electron trajectories. Thereby, in order to describe the metastable excited constellation of the electrons in the Helium atom which enables the thermal radiation exchange, an *eccentric asymmetric harmonic oscillator* was adduced comprising the orbits of the two diametrically positioned electrons. It could be connected with the kinetic behaviour of the Helium-atoms, thus bridging quantum mechanics with thermodynamics. However, a number of significant computation errors have since been identified, which were corrected. Several points of the recently published paper could be herewith cleared and revised. In particular, the deflection distances, which are relevant for the used eccentric asymmetric oscillator, could be precisely computed, as well as the oscillation energy of the electrons which was consistent in the total deflection energy. Moreover, the theorem of momentum which must be fulfilled in order to bridge the electronic oscillation and the thermal motion could be modified in such a way that all results are compatible. Beyond that, a solution was found in order to implement the law of energy conservation which had been neglected so far, namely by application of the modulo-rule leading to lower partial oscillation energies. Moreover, a direct concordance was found between the electromagnetic radiation and the electronic oscillation, excluding the previously used Einstein relation for the photoelectric effect.

## Keywords

Kinetic Gas Theory, 2D-Atom Model of Helium, Thermal Radiation Absorption and Emission by Gases, Electronic Oscillation Model, Bridge Thermodynamics/Quantum-Mechanics

## 1. Introduction

In a recently published paper [1] the thermal radiative behaviour of Helium, which had been reported already in 2016 [2], was quantum-mechanically explained using a planar atom model with well-defined electron trajectories [3]. Thereby, in order to describe the metastable excited constellation of the electrons in the Helium atom which enables the thermal radiation exchange, an *eccentric asymmetric harmonic oscillator* was adduced comprising the orbits of the two diametrically positioned electrons. It could be linked to the kinetic behaviour of the Helium-atoms by applying the kinetic gas theory and taking into account the law of conservation of momentum, thus bridging quantum mechanics with thermodynamics. However, in [3] meanwhile some significant computation errors have been discovered which were corrected. They concern the deflection distances of the eccentric harmonic oscillator as well as the oscillation energy of the electrons. Furthermore, the relationship between electronic vibration and thermal motion can be formulated in such a way that all results are consistent with one another. Beyond that, the theory could be extended, considering the law of energy conservation, and modified with respect to the connection between the electronic oscillation frequency and the radiation frequency. In order to facilitate the understanding, the contents are subdivided in three parts, namely in a summary of the here relevant topics, a rectification of the existing theory, and an extension and modification of the theory.

## 2. Summary of the Here Relevant Topics

### 2.1. The Thermal-Radiative Behaviour of Helium

The fact that Helium can adsorb and emit thermal radiation, combined with warming-up and cooling-down, was incidentally discovered by the author during measurements carried out on air and on $CO_2$ in order to empirically verify atmospheric temperature increase as a result of its concentration increase which is allegedly responsible for climate change. In contrast to the previous IR-measurements, where solely the radiation absorption had been measured, now the temperature increase of the gases in the presence of thermal radiation was assessed. Surprisingly, air did not only behave like pure $CO_2$; moreover, every gas turned out to be active, even noble gases such as Helium. Thus, the results for Helium could be adduced for a quantum mechanical interpretation, which was delivered in the later publication [1], and which will be discussed below. The used apparatus and the results as well as their evaluation in terms of the kinetic gas theory are described in [2]. Afterwards, they are briefly resumed.

The measurements were carried out in one meter long tubes, applying as radiation sources sunlight, on the one hand, and IR-spots, on the other hand. In order to avoid or minimize interference in the walls of the measuring tube, due to the generally low heat capacity of gases, a material with low heat capacity and low heat conductivity was used, namely Styrofoam. Gradually, additional improvements were made by thin aluminium foils mirroring the heat radiation. The gas was en-

closed by thin plastic foils at both ends of the tube, and the temperatures were measured by thermometers at three positions, see Figure 1 and Figure 2.

Figure 1. Solar tube (Figure 5 from Ref. [2]).

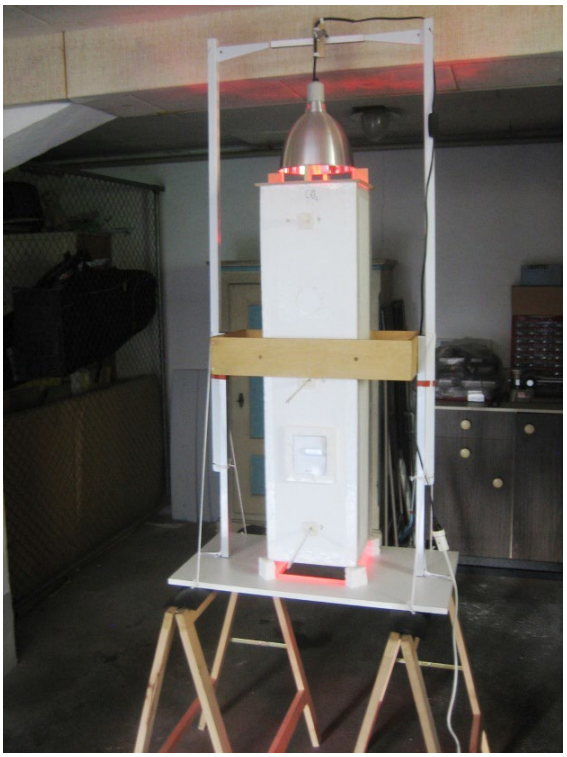


Figure 2. Heat radiation tube (Figure 3 from Ref. [2]).

The advantage of the first method is that the sunlight intensity remains constant along the tube. However, the portion of thermal radiation is relatively low. Moreover, its intensity is not constant but depends on the daytime, the time of year and the sea level of the measuring station. Therefore, the measurements were always made in the summer at midday.

The advantage of the second method, using artificial light, is that the light intensity is constant. However, it decreases along the tube even if it is not absorbed since the intensity of light sent by a point source depends on the distance. Moreover, it was difficult to estimate the effective wave length – or even wave lengths – using Planck's formula which delivers the wave length dispersion depending on the spot-intensity, solely based on the rough indications of the producer. By combining the solar spectrum with the spectrum of the IR-spot approximate values for the effective wavelength were obtained, being lower than 2 μm. For comparison: the limit to the visible red light is at 0.76 μm. As subsequent but less reliable measurements using a hot plate yielded [4], larger wavelengths seem to be possible, too.

The essential result of those measurements consisted in the observation that any gas is warmed-up when it is thermally irradiated, but solely up to a limiting temperature where the thermal absorption intensity of the gas is equal to its emission intensity. This effect was first observed in air and in $CO_2$, whereby the limiting temperatures were nearly equal. But it also occurred in the noble gases Argon, Neon and Helium, whereby the limiting temperatures depended on the type of gas, see **Figure 3** and **Figure 4**.

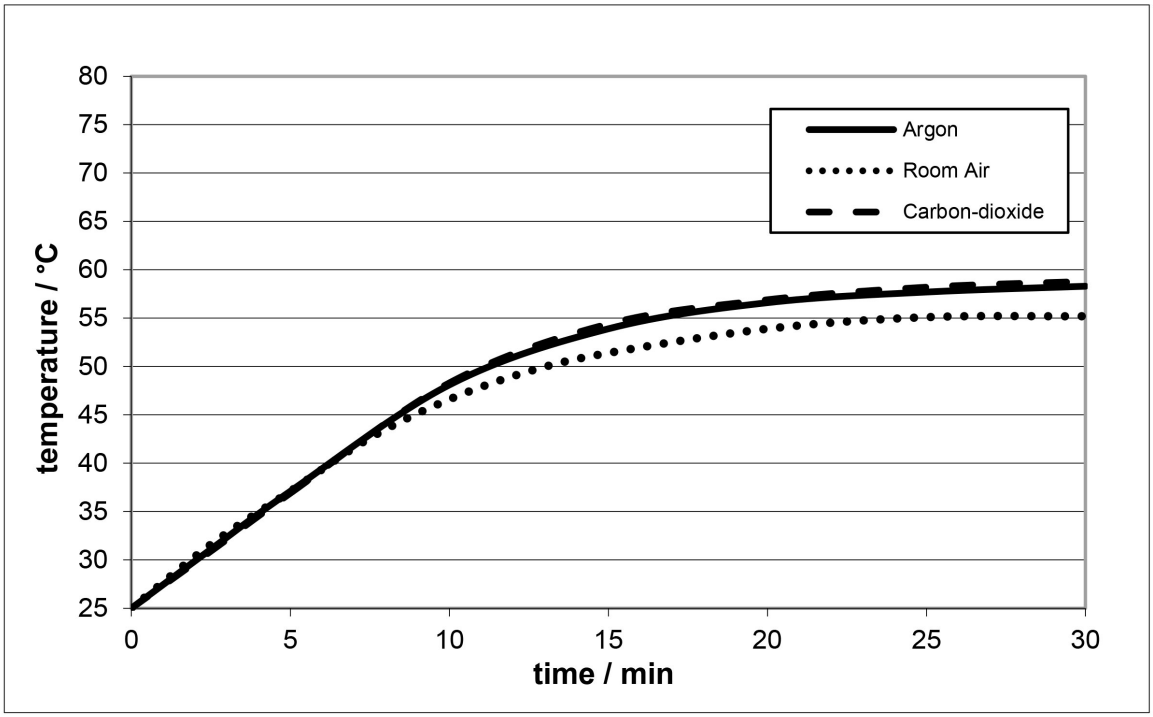



**Figure 3.** Average warming-up rates for different gases, measured with the heat radiation tube (method A, 150 W IR-spot, medium thermometer position) (Figure 25 from Ref. [2]).

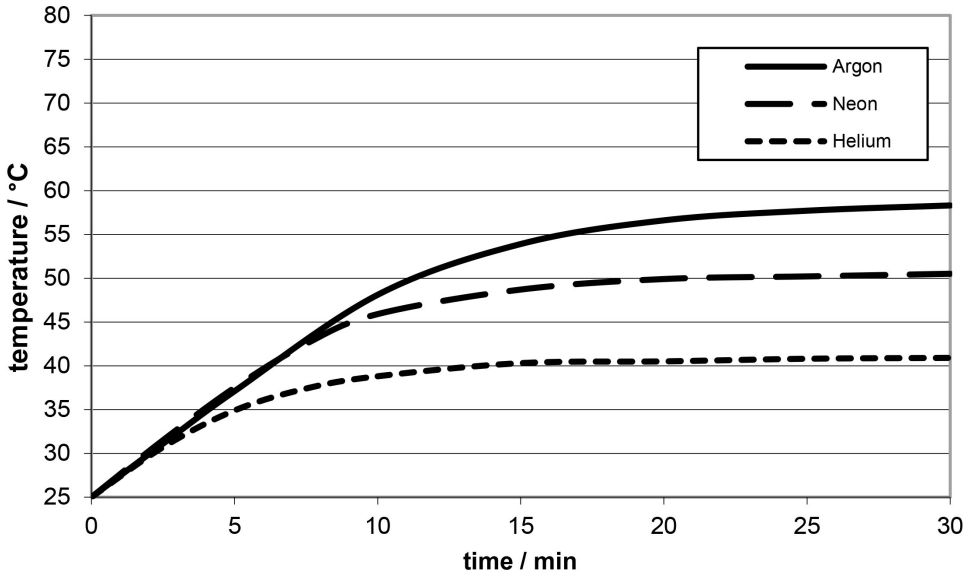



**Figure 4.** Average warming-up rates for different gases, measured by the heat radiation tube (method A, 150 W IR-spot, medium thermometer position) (Figure 26 from Ref. [2]).

These differences could be explained by the kinetic gas theory which presumes proportionality between the kinetic energy of the gas particles and the absolute temperature, according to Equation (1):

$$\overline{E}_{kin,atom} = \frac{1}{2} m \overline{w}^2 = \frac{3}{2} k_B T = \frac{3RT}{2N_A} \rightarrow \overline{w} = \sqrt{\frac{3RT}{M}} \tag{1}$$

$m$ = mass of a single particle (atom or molecule) = molar atom mass $M/N_A$

$N_A$ = Avogadro Constant = $6.022 \times 10^{23}$

$\overline{w}$ = average velocity of this particle

$k_B$ = Boltzmann Constant = $R/N_A = 1.381 \times 10^{-23}$ J·K$^{-1}$

$R$ = Gas Constant = 8.314 J·K$^{-1}$·mol$^{-1}$

$T$ = absolute temperature

In order to interpret this radiative behaviour, proportionality was assumed between the collision wattage of the atoms and the radiation wattage. As a consequence, proportionality between radiation wattage and gas pressure was predicted, but it could not be exactly computed. However, an empirical proof was furnished in a later publication [5] where measurements at different altitudes—implying different atmospheric pressures—were made. Similar results for air, Carbon-dioxide and Argon were published later on by Seim and Olsen [6], but without delivering such an interpretation.

A quantum mechanical explanation was already taken into consideration in [2] and in [4] but only realized in [1], using the newly developed planar atom model of Helium with well-defined electron trajectories [3], and assuming that there is an electromagnetic interaction between the thermal radiation and the oscillation of the electronic shell (orbit). But as incipiently mentioned, the respective computation has to be partly revised. Thereto, this model has to be shortly elucidated.

### 2.2. Description of the Here Relevant Atom Model of Helium

The here used atom model of Helium relies on the original atom model of Hydrogen published by Niels Bohr in 1913, thus equilibrating the Coulomb force and the centrifugal force between the immobile nucleus and the rotating electrons. Using Einstein's relation concerning the photoelectric effect, published in 1905 and based on Planck's quantum theory, published in 1900, he connected the discrete UV-spectrum of atomic hydrogen with the existence of energetically excited metastable electronic states. The computation yields that the (planar) electron orbits exhibit an integer multiple $n$ of the angular momentum $h/2\pi = \hbar$, whereby $r_n$ = electronic rotation radius, dependent on $n$, and $m_{el}$ = electron mass. In order to avoid an ambiguity error with the frequency $\nu$, the electron velocity is here indicated with $u$:

$$u_{rot,n} \cdot r_n \cdot m_{el} = n \cdot \frac{h}{2\pi} \tag{2}$$

Therefore, $h$ (which exhibits the unit J·s) should rather be named "quantum of angular momentum", instead of "quantum of action" (as it is usual).

However, the fact could not be explained why the electron does not fall onto the nucleus but remains in a ground state. Induced by Louis de Broglie's hypothesis of the wavy nature of the electron movement and the formation of standing waves, wave mechanics were developed by Heisenberg, Schrödinger and others, assuming probabilities of presence and denying well-defined planar electron trajectories.

But the existence of this stable ground state can be really explained, namely by the *electron spin* which had been discovered by Uhlenbeck and Goudsmith in 1925/26, and which induces spin-orbit coupling. As a consequence, the spin of the electron acts as a *perpetuum mobile* which isn't destroyable. But instead of building the theory upon the spin, it was implemented into the already existing theory in the aftermath. Indeed, the existence of planar hydrogen atoms could be verified in the case of $H_2$-molecules [7].

This construction principle can be applied onto the Helium atom model, too. However, the existence of two electrons seems to infringe the Pauli-principle if both electrons move in the same orbit. The key principle of that model consists in the hypothesis that both electrons which diametrically circle round the nucleus obeying the conservation of momentum $\hbar$. But since their partial three-dimensional pathways proceed orthogonally, the resulting mutual pathway is two-dimensional, exhibiting the angular momentum $\sqrt{2}\hbar$ (cf. **Figure 5**).

$$u_{rot} \cdot R \cdot m_{el} = \sqrt{2} \cdot \frac{h}{2\pi} = \sqrt{2} \cdot \hbar \tag{3}$$

This model is two-dimensional, thus it is in contradiction to the orthodox atom model which provides for the two electrons a three-dimensional, cloudy 1s-orbital. However, it describes an isolated Helium atom in the ground state. In reality, each atom is part of a gas, being in a translation as well as in a rotation move. And as a

consequence of this rotation, it apparently becomes three-dimensional. Thereby, stochastic thermodynamics—particularly the kinetic gas theory—and exact quantum-mechanics can be bridged theoretically, as scheduled in Figure 6.

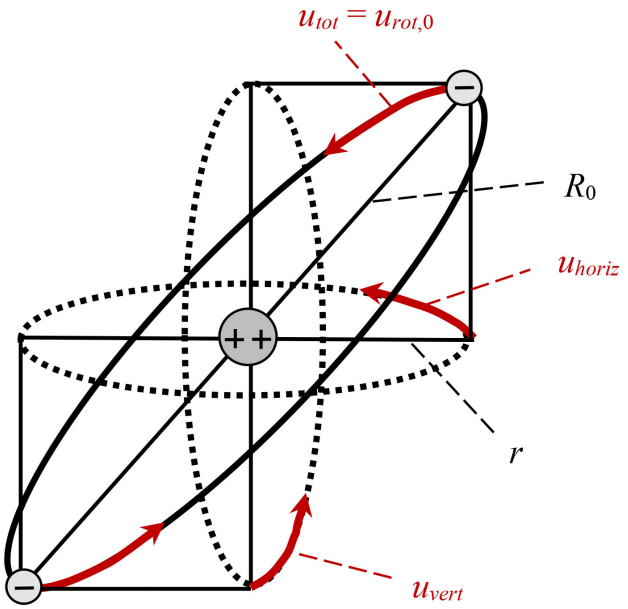



**Figure 5.** 2D-model of Helium composed by two imaginary orthogonal orbits of the electrons (Figure 10 from Ref. [3]) $R_0 = 0.5644 \times 10^{-10}$ m $u_{rot,0} = 2.901 \times 10^{6}$ m·s$^{-1}$ $\omega_0 = 5.14 \times 10^{16}$ s$^{-1}$.

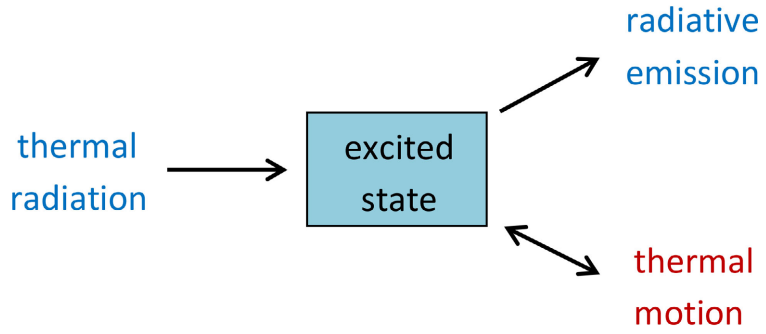



**Figure 6.** Scheme of the energetic relationships in the atom (Figure 9 from Ref. [1]).

But first of all, the behaviour of the electrons in a single atom has to be considered as a result of the collision with another atom or of a thermal radiative excitation, inducing in the ground state a pulsation of the electronic shell (orbit) in the form of an *eccentric asymmetric harmonic oscillator.* Its revised form will be described in the next chapter.

## 2.3. Description of the Eccentric Asymmetric Harmonic Oscillator

Using this model, an *excited metastable electronic state* can be supposed which enables absorption as well as emission of electromagnetic radiation, being—be-

yond that—capable to transfer kinetic energy to another atom. And as it would seem obvious, the energy of the excited state should have the character of an *eccentric oscillation,* superimposed on the rotation of the electrons, and in combination with the rotation inducing a *pulsation*. Thereby, it has to be regarded that, due to heat motion, the atoms are not immobile. Rather, they move not only in the form of translation but also in the form of rotation (here called *full rotation*) which both are not quantised. Thus, viewed from the position of an outside observer, the atom appears to pulsate in all directions, due to the oscillation of the electron orbit.

The constellation of a single Helium atom is depicted in Figure 7, expressing a standing wave:

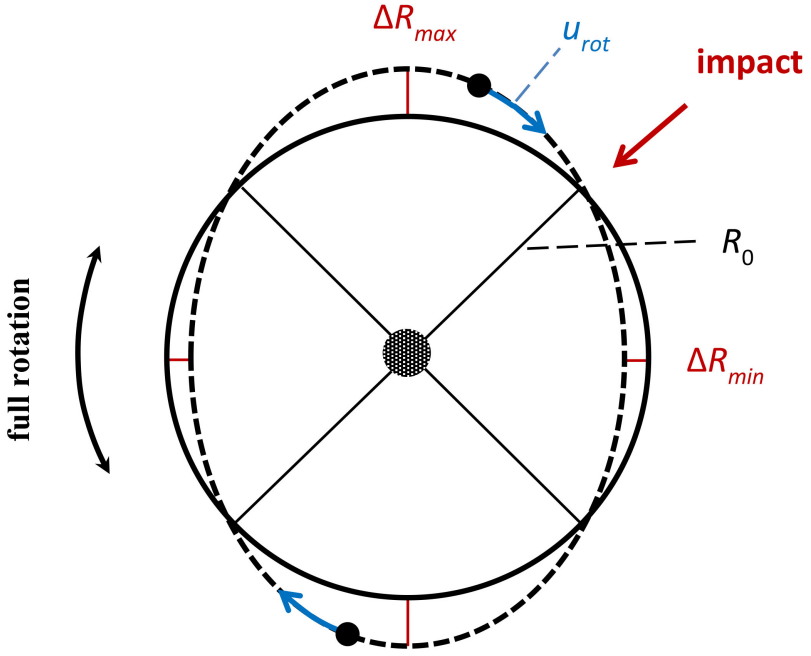



Figure 7. Orbit of the electrons as a result of a collision or a thermal-radiative excitation (= dotted curve; red lines: maximum and minimum positions of the electrons) (Figure 10 from Ref. [1]).

Therein, two different electron velocities occur, the *rotation velocity* $u_{rot}$ and the *oscillation velocity* $u_{osc}$ which is eccentrically grafted on the former one. Both can be described mathematically. But while the former value is (approximately) constant, the latter varies and reaches its maximum value at the zero point. Thereby, this maximum velocity $u_{osc,max}$ (in [1] referred to $u_{osc,turn}$) is responsible for the total energy of the oscillator which is given by its kinetic energy at this point. It is proportional to the (constant) angular velocity $\omega_{osc}$.

This is true for any harmonic oscillator, also for an asymmetric one like that which exists here. It can be formulated by Equation (4), and depicted as a wavy line in Figure 8.

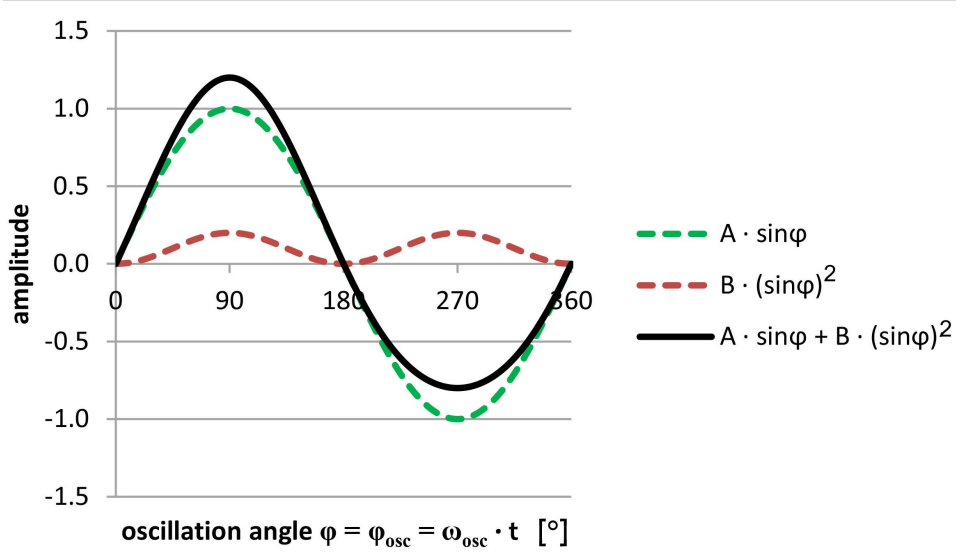



**Figure 8.** Wavy depiction of an asymmetric harmonic oscillator (projection of the angular positions on a circle) (Figure 11 from Ref. [1]).

$$\Delta R = A \cdot \sin \varphi_{osc} + B \cdot \left(\sin \varphi_{osc}\right)^2 \tag{4}$$

$\Delta R$ = deflection distance

$A = \left(\Delta R_{max} + \Delta R_{min}\right)/2$

$B = \left(\Delta R_{max} - \Delta R_{min}\right)/2$

$\varphi_{osc} = \omega_{osc} \cdot t$ ($t$ = time)

The oscillation velocity $u_{osc}$ matches the mathematical derivation of the deflection distance $\Delta R$ (given by Equation (4)) and becomes a function of time, expressed by Equation (5):

$$u_{osc} = \Delta \dot{R} = A \cdot \omega_{osc} \cdot \cos\left(\omega_{osc} t\right) + 2B \cdot \omega_{osc} \cdot \cos\left(\omega_{osc} t\right) \cdot \sin\left(\omega_{osc} t\right) \tag{5}$$

That yields for the two electrons at the zero point (where $\omega_{osc} \cdot t = 0$ and $u_{osc}$ = maximal) according to Equation (4) the kinetic energy, which corresponds to the oscillation energy:

$$E_{osc} = m_{el} \cdot \left(u_{osc,max}\right)^2 = m_{el} \cdot A^2 \cdot \left(\omega_{osc}\right)^2 \tag{6}$$

$m_{el}$ = electron mass = $0.9109 \times 10^{-30}$ kg

$A$ = amplitude, according to Equation (4)

Figure 8 shows the deflection distance (=amplitude) as a function of the oscillation angle which could be visualized by its projection onto a circle. If, instead, it should be depicted as a function of the rotation angle $\varphi_{rot}$, Equation (4) may be used, too, but inserting $\varphi_{rot} = 2\varphi_{osc}$.

Figure 9 explains the occurrence of the four zero points which are evident in Figure 7. It suggests that, due to the periodic character of the sinus and the cosine function, the existence of several zero points does not affect the energetic condition which only depends on the deflection distances. In other words, the oscillation energy of the electrons is independent of the number of oscillations.

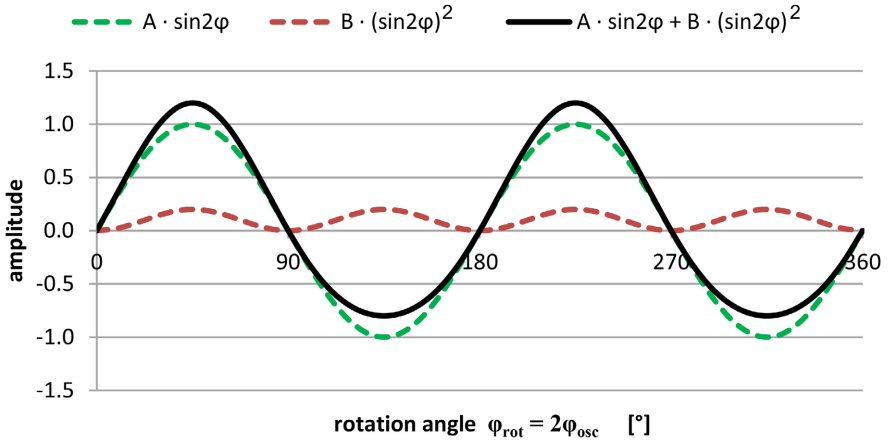



**Figure 9.** Connection of two asymmetric harmonic oscillators as a function of the rotation angle.

Moreover, the eccentric character of the oscillation has to be taken into account. As already mentioned—and as it is evident in **Figure 7**—the oscillation is grafted on the rotation which implies that the rotation radius $R$ becomes $R_0 \pm \Delta R$. Thereby, the $\Delta R$-values are not equal but depend on the position, *i.e.* $\Delta R_{out}$ is larger than $\Delta R_{in}$ (as a consequence of the different distance dependency of the Coulomb attraction between nucleus and electrons and their centrifugal force). Thus, $\Delta R_{out}$ corresponds to $\Delta R_{max}$, while $\Delta R_{in}$ corresponds to $\Delta R_{min}$.

Thereby, an approximation was made by assuming $\omega_{rot}$ as constant. This is actually not the case since the orbital angular momentum must be constant, thus the rotation velocity $u_{rot}$ as well as the angular velocity $\omega_{osc}$ depend on the rotation radius $R$, according to Equation (7):

$$u_{rot} \cdot R \cdot m_{el} = \omega_{rot} \cdot R^2 \cdot m_{el} = \sqrt{2} \cdot \frac{h}{2\pi} \rightarrow \omega_{rot} = \sqrt{2} \cdot \frac{h}{2\pi} \cdot \frac{1}{R^2 \cdot m_{el}} \tag{7}$$

However, the deviation of $R$ is little since the $\Delta R$-values are relatively small.

In order to determine the $\Delta R$-values, the condition can be applied that the total energy of the electrons, composed by the potential and the kinetic energy, must be equal at their outer and at their inner position. This computation was already made in [1]. However, it contains several special errors which require a revision of the computation.

## 3. Rectification of the Existing Theory

### 3.1. The Determination of the Asymmetric Parts at the Oscillator

In order to determine the extreme distances $R_{out} = R_0 + \Delta R_{max}$ and $R_{in} = R_0 - \Delta R_{min}$ of the two diametrically running electrons at the eccentric asymmetric harmonic oscillator, described by Equation (4), their energy contents have to be computed as a function of $R$ and equated at their relevant value. Their energy contents are given by the sum of the potential energy and the rotation energy, while the oscillation energy $E_{osc}$ is zero at these positions.

The *potential energy* can be computed using the expression for the Coulomb-force, illustrated in **Figure 10** and formulated by Equation (8) (according to [3]):

$$F_{Coul} = \frac{15K}{8R^2} \rightarrow E_{pot} = \frac{15K}{4R} \tag{8}$$

$R$ = total radius between the nucleus and the electrons

$K = e^2/4\varepsilon_0 = 2.307 \times 10^{-28}\ \mathrm{J \cdot m}$

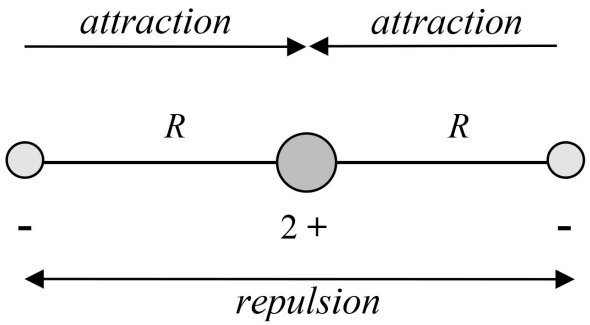



**Figure 10.** Interference of the Coulomb forces at the equator (Figure 11 from Ref. [3]).

However, here the value for $E_{pot}$ is assumed as twice as much as in the approach made in [1], due to the existence of two electrons.

The computation of the *kinetic energy* and thus of the rotation velocity $u_{rot}$ requires the implementation of the angular momentum $\sqrt{2}\hbar = \sqrt{2}h/2\pi = 1.0546 \times 10^{-34}\ \mathrm{J \cdot s}$ according to Equation (3), and yields the value given in Equation (9):

$$u_{rot} = \sqrt{2} \cdot \frac{h}{2\pi} \cdot \frac{1}{R} \cdot \frac{1}{m_{el}} \tag{9}$$

Thereby, it has also to be regarded that both electrons contribute to the kinetic energy, thus

$$E_{kin} = m_{el} \cdot \left(u_{rot}\right)^2 = 2 \cdot \left(\frac{h}{2\pi}\right)^2 \cdot \frac{1}{R^2} \cdot \frac{1}{m_{el}} \tag{10}$$

Using these relations, the energies $\Delta E_{tot} = \Delta E_{pot} + \Delta E_{kin}$ can be computed for the outer position as well as for the inner position of the electrons, using the Equations (11)-(14):

$$\Delta E_{pot,out} = \frac{15K}{4} \cdot \left[\frac{1}{R_0} - \frac{1}{R_0 + \Delta R_{out}}\right] \tag{11}$$

$$\Delta E_{pot,in} = \frac{15K}{4} \cdot \left[\frac{1}{R_0} - \frac{1}{R_0 - \Delta R_{in}}\right] \tag{12}$$

$$\Delta E_{kin,out} = 2 \cdot \left(\frac{h}{2\pi}\right)^2 \cdot \left[\frac{1}{\left(R_0 + \Delta R_{out}\right)^2} - \frac{1}{R_0^2}\right] \tag{13}$$

$$\Delta E_{kin,in} = 2 \cdot \left(\frac{h}{2\pi}\right)^2 \cdot \left[\frac{1}{\left(R_0 - \Delta R_{out}\right)^2} - \frac{1}{R_0^2}\right] \tag{14}$$

This equation system contains two unknowns, namely $\Delta R_{out}$ and $\Delta R_{in}$. Their determination would be possible if two equations were available. An additional relation is possible by equalizing of the total energies, according to Equation (15):

$$\Delta E_{tot} = \Delta E_{pot} + \Delta E_{kin} = \Delta E_{pot,out} + \Delta E_{kin,out} = \Delta E_{pot,in} + \Delta E_{kin,in} \tag{15}$$

In [1] it has not been realized that this equation system is solvable, namely by nested integrals, yielding $\boldsymbol{\Delta R_{out} = 0.045 \times 10^{-10}\ \mathrm{m}}$ and $\boldsymbol{\Delta R_{in} = 0.0387 \times 10^{-10}\ \mathrm{m}}$, thus delivering the value $\boldsymbol{A = 0.04185 \times 10^{-10}\ \mathrm{m}}$. Moreover, the evaluated value of $\Delta \boldsymbol{E_{tot}}$ is $\boldsymbol{0.0416 \times 10^{-18}\ \mathrm{J}}$. On the other hand, $\boldsymbol{E_{osc}}$ (which should be equal to $\Delta E_{tot}$) can be computed by using Equation (6). When $\omega_{osc} = \omega_{rot} = 5.14 \times 10^{16}\ \mathrm{s^{-1}}$, it becomes $\boldsymbol{0.0421 \times 10^{-18}\ \mathrm{J}}$. Thus, the accordance of the two values is excellent. The application of $\omega_{osc} = \omega_{rot}$ (instead of $\omega_{osc} = 2\omega_{rot}$) seems striking. However, it solely means that the oscillation period, defined as $2\pi/\omega_{osc}$, is half as long as the rotation period, while the particular oscillation energies are not additive.

*For comparison*: In [1] different and inconsistent values for $\Delta R$ are given. While on page 3610 above $A = 0.0355 \times 10^{-10}$ m and $E_{osc} = 0.121 \times 10^{-18}$ J are assumed, on page 3611 the values $\Delta R_{in} = 0.068 \times 10^{-10}$ m and $\Delta R_{out} = 0.1035 \times 10^{-10}$ m are given, yielding $A = 0.08575 \times 10^{-10}$. And in particular, in Figure 14, the values for $\Delta E_{tot,in}$ and $\Delta E_{tot,out}$ differ altogether instead of being equal at a specific position (and, beyond that, being equal to $E_{osc}$).

Finally, the bridge between electron oscillation and thermal motion, thus between quantum mechanics and thermodynamics, has to be rechecked with respect to the description delivered in [1]. It requires some correction, too, even if the approach is principally accurate.

### 3.2. The Bridge between Electronic Oscillation and Thermal Motion

The key idea for bridging electronic oscillation and thermal motion consists in the application of the *theorem of conservation of the momentum* $\boldsymbol{P}$ to the collision process according to Equation (16), whereby $u_{osc,max}$ means the *electron velocity* at the zero point and $w$ the atom or particle velocity due to thermal motion. Thus, the momentum of the atom as a whole is equated with the momentum of the electrons within the atom. However, different from the respective approach made in [1], the factor **2** is implemented:

$$\boldsymbol{P}_{electron} = 2m_{el} \cdot u_{osc,max} = \overline{\boldsymbol{P}}_{atom} = m_{\mathrm{He}} \cdot \Delta\overline{w}_{\mathrm{He}} \rightarrow \Delta\overline{w}_{\mathrm{He}} = u_{osc,max} \cdot \frac{2m_{\mathrm{el}}}{m_{\mathrm{He}}} \tag{16}$$

Since $u_{osc,max} = A \cdot \omega_{osc}$ and $\omega_{osc} = \omega_{rot}$ (see above), $u_{osc,max}$ becomes $0.216 \times 10^{6}$ $\mathrm{m \cdot s^{-1}}$. Using the values $m_{\mathrm{He}} = 0.664 \times 10^{-26}$ kg and $m_{el} = 0.9109 \times 10^{-30}$ kg, $\Delta\overline{w}_{\mathrm{He}}$ becomes $\boldsymbol{59\ \mathrm{m \cdot s^{-1}}}$.

On the other hand, it can be computed by Equation (1), delivering Equation (17), and evaluating the temperature values from **Figure 11** ($T_{lim,\mathrm{He}} = 324$ K and $T_{amb} = 298$ K):

$$\Delta\overline{w}_{\mathrm{He}} = \sqrt{\frac{3R}{m_{\mathrm{He}}}} \cdot \left(\sqrt{T_{lim}} - \sqrt{T_{amb}}\right) \tag{17}$$

Thereby, it has to be considered that $\sqrt{T_{lim}} - \sqrt{T_{amb}} \neq \sqrt{T_{lim} - T_{am}} = \sqrt{\Delta T}$ .

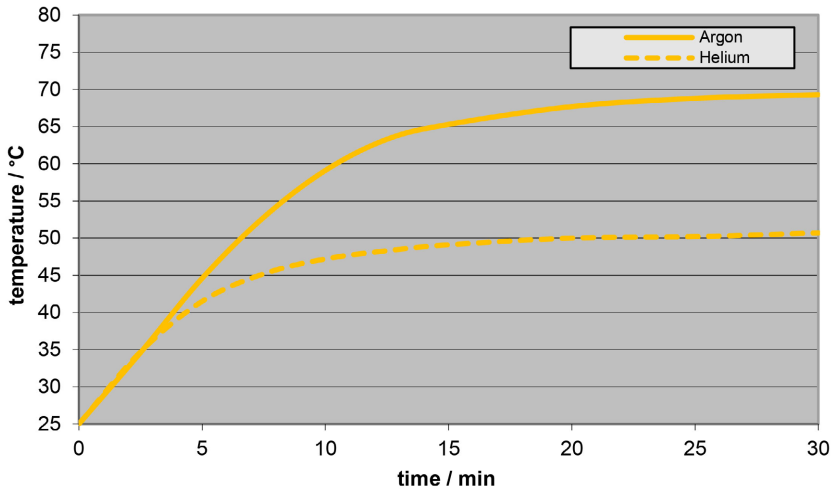



Figure 11. Comparison of Argon and Helium (method B2, 150 W, medium pos.) (Figure 27 from Ref. [2]).

The obtained value of **58 m·s$^{-1}$** is very close to the theoretical one.

While the theorem of conservation of the momentum herewith could be fulfilled in the bridging process, the *law of energy conservation* has not been taken into account so far. Thereby, it is evident that the oscillation energy must not be larger than the kinetic energy-difference between the excited state and the initial state. Considering Figure 11 (with $\Delta T = 26$ K) and using Equation (1), $\Delta E_{kin,atom}$ becomes $5.4 \times 10^{-22}$ J, thus approx. 78 times less than the oscillation energy which has been determined in Chap. 2.1., namely $0.042 \times 10^{-18}$ J. A theoretical explanation which has not been applied so far is given in the next chapter.

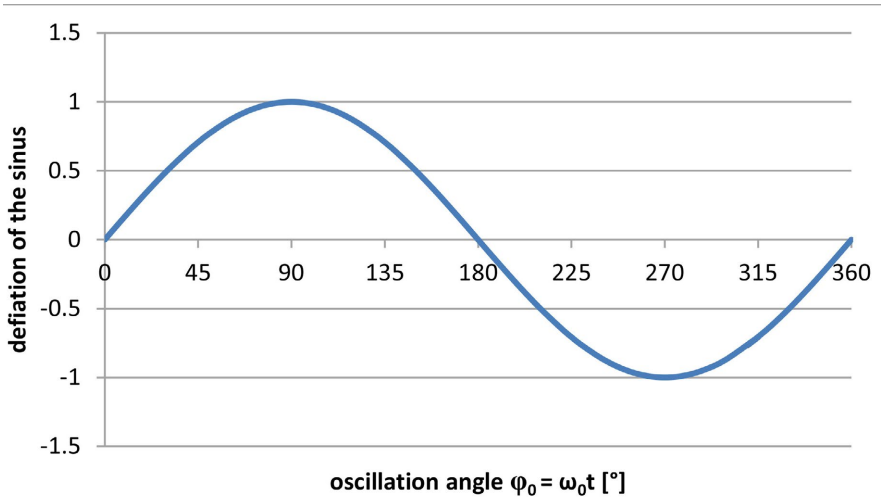
## 4. Extension and Modification of the Theory

### 4.1. The Energy-Exchange at the Bridging Process

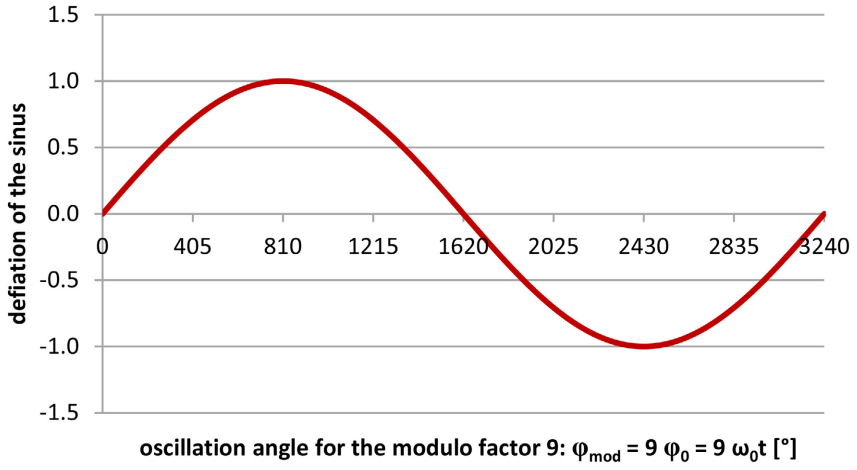
Proceeding from the fact that the excitation energy of the here used eccentric asymmetric harmonic oscillator is larger than the kinetic energy difference, which is due to atomic collisions (see above), the former has to be scaled down in order to fulfil the law of energy conservation.

Considering that $E_{osc}$ depends on $(\omega_{osc})^2$, the angular velocity $\omega_{osc}$ should be at least $\sqrt{78} = 8.8$ times smaller, which would result in a corresponding reduction of the oscillation frequency. However, this seems not to be readily possible since the condition must be fulfilled that the sine-values as well as the cosine-values of the oscillation angle—thus of the product angular velocity and time—must be equal at any 45˚-step (where an inversion of the course occurs). That is not the case for any arbitrary factor.

But a solution is possible by applying the so-called *modulo-rule*, delivering the quotient **9** as the lowest possible value. It is fundamentally demonstrated in Figure 12(a) and Figure 12(b).




(a)




(b)

**Figure 12.** (a) Course of a normal harmonic oscillator; (b) Course of the modulo-adapted normal harmonic oscillator.

This means that

$$\omega_{osc,part} = \frac{\omega_{rot}}{9} = 0.571 \times 10^{16}\ \mathrm{s}^{-1} \tag{18}$$

Using Equation (6) with $A = 0.04185 \times 10^{-20}$ m, this yields the value $\boldsymbol{E_{osc,part} = 5.2 \times 10^{-22}\ \mathrm{J}}$ which is very close to the empirical value of $5.4 \times 10^{-22}$ J. It means that the oscillation period becomes nine times smaller, *i.e.* the oscillation becomes slower.

Finally, the connection between the oscillation energy (or frequency) and the thermal radiation energy (or frequency) has to be found.

## 4.2. The Connection of the Oscillation Energy with the Thermal Radiation Energy

Obviously, there exists a correlation between the oscillation frequency (and thus

the oscillation energy) and the thermal radiation energy (and thus the radiation frequency). So far, Einstein's relation for the photoelectric effect was adduced, namely $E = h \cdot \nu$. If we insert the here found value for the oscillation energy 0.042 $\times 10^{-18}$ J, this yields a radiation frequency of 0.634 $\times 10^{14}$ $s^{-1}$ and a wave length of 4.73 μm (since $\nu \cdot \lambda = c = 3 \times 10^8$ $m \cdot s^{-1}$).

The problem is that the frequency and the corresponding wave length of the effective thermal radiation, indicated in [2], are not exactly known but solely estimated, as mentioned in Chap. 2.1. The preferred wavelength $\lambda_{rad}$ was 1.9 μm, yielding $\nu_{rad} = 1.58 \times 10^{14}$ $s^{-1}$. However, further wave lengths were considered possible, while according to [4] and [6] even a larger wave length seems possible.

According to this, there is no consistency between the computed and the empirical value, unless we assume that the empirical value is not correct. The discrepancy is even larger, if we use instead of the full oscillation energy its ninths part—according to the modulo-rule—, as the radiation frequency then becomes nine times smaller while the wave length becomes even nine times larger.

Thereby, the question arises whether, contrary to Einstein's relation, a direct correlation exists between the oscillation frequency and the radiation frequency. If we use $\omega_{rad} = \omega_{osc} = \omega_{rot} = 5.14 \times 10^{16}$ $s^{-1} \rightarrow \nu_{rad} = 0.818 \times 10^{16}$ $s^{-1}$, we get $\lambda_{rad} =$ 0.037 μm, which is obviously all too small. But if we use the partial value due to modulo, the wave length becomes 0.33 μm, which is ever so close to the empirical value. And if we, moreover, consider that further modulo values are possible, namely all the ones exhibiting a multiple of 9, a variety of wave lengths come into question, *i.e.* those with the wave lengths 0.66, 0.99, 1.32, 1.65, 1.98, 2.31, 2.64, 2.97 μm etc. Thereby, those with a wave length larger than 0.76 μm are in the IR-range.

Indeed, *it seems plausible that several wave lengths exist together*, *implicating a continuous-like spectrum*, *instead of a discrete one*. This would also explain why it is so difficult to identify the wavelength which is effective for the thermal radiation and adsorption.

## 5. Conclusion

Proceeding from the recently published atom model of Helium which is characterized by planar electron trajectories [3], and considering the empirical data given in [2], several key points of the recently published paper concerning the quantum-mechanical explanation of the thermal radiative behaviour of Helium [1] could be herewith clarified and revised. In particular, the deflection distances, which are relevant for the used eccentric asymmetric oscillator, could be precisely computed, as well as the oscillation energy of the electrons which was consistent in the total deflection energy. Moreover, the theorem of momentum which must be fulfilled in order to bridge the electronic oscillation and the thermal motion could be modified in such a way that all results are compatible. Beyond that, a solution was found in order to implement the law of energy conservation which had been neglected so far, namely by the application of the modulo-rule leading

to lower partial oscillation energies. Moreover, a direct concordance was found between the electromagnetic radiation and the electronic oscillation, excluding the previously used Einstein relation for the photoelectric effect. Thereby, the conclusion was drawn that several wave-lengths are involved together.

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## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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