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Study of the Charged Fullerene Molecule with Single Spin Electrons

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Abstract

Through this work, we were able to study the movement of the fullerene molecule charged with electrons with a definite spin. After analysing the obtained results, we concluded that the fullerene molecules charged with electrons, whether with a lower spin or with an upper spin, decrease their path length and their maximum velocity as their charge increases. The fullerene molecules charged with lower spin electrons have a longer path than the fullerene molecules charged with upper spin electrons. We also found that the fullerene molecules charged with lower spin electrons are faster than the fullerene molecules charged with upper spin electrons.

1-Introduction

Spintronics is a branch of modern physics that focuses on studying the electrons in materials [1-4], which have a property called electron spin, and how this property can be exploited in the design and development of electronic devices [5-6]. The properties of spin-electrons are easily controllable, which opens up the possibility of developing new electronic devices with higher performance and greater efficiency. This field has wide-ranging applications in computing, electronic storage [7-8], communication, energy, and medicine [9-10].
Spintronics technology is ideal for developing advanced electronic devices, enabling us to design data storage devices with greater capacity and better performance [11-13], faster and more efficient computing devices, and advanced medical devices and sensors such as thermal, chemical, and biological sensors [9,14]. Spintronics relies on quantum physics, electronics, and magnetism, requiring a careful study of the properties of materials and their interactions with spin-electrons. It has promising fields for research and development in the future, making it a vital and important science for the future of technology and science [15-16], and there are several research studies that have been conducted in this field [17-22].
In this work, we will discuss the study of the movement of the liberated fullerene molecules [23-25] by shining laser beams on the original collected material, by following their path through the electromagnetic field, extracting and analysing the motion equations for one molecule, and then generalizing them using the digital program in the Fortran language, in order to know the behaviour of these secondary particles in these conditions.

2-Experimental design

This design is based on studying the movement of secondary molecules (fullerenes). in an electromagnetic medium, where they are dismantled by a laser. Figure (1) shows the experimental design for this study, as it consists of a laser pumping source, which shines laser beams on the fullerene (C60) and the laser is pumped by a flash lamp with a frequency of 20 HZ. In this experimental design, a Nd Yag laser with a wavelength of (164nm) was used, as the latter operates with a matter, i.e., braking system of pulses that carry energy in the range of 10 to 100 mJ, and this energy is considered sufficient to extract some particles of that each pulse reaches the mold has a time ranging from 5 to 20 nanoseconds. When the laser is fired, energy is released to breaking the carbon bonds, done. These secondary balls are either with electrons, the carbon bonds are released and gives the fullerene secondary molecules energy to move towards the region it is (spin up), or spin down electrons.
After passing through the injection area, spin up particles are obtained. And another with spin down, where after passing these particles move towards the electromagnetic field, and there their movement is studied by analyzing the equations of motion.

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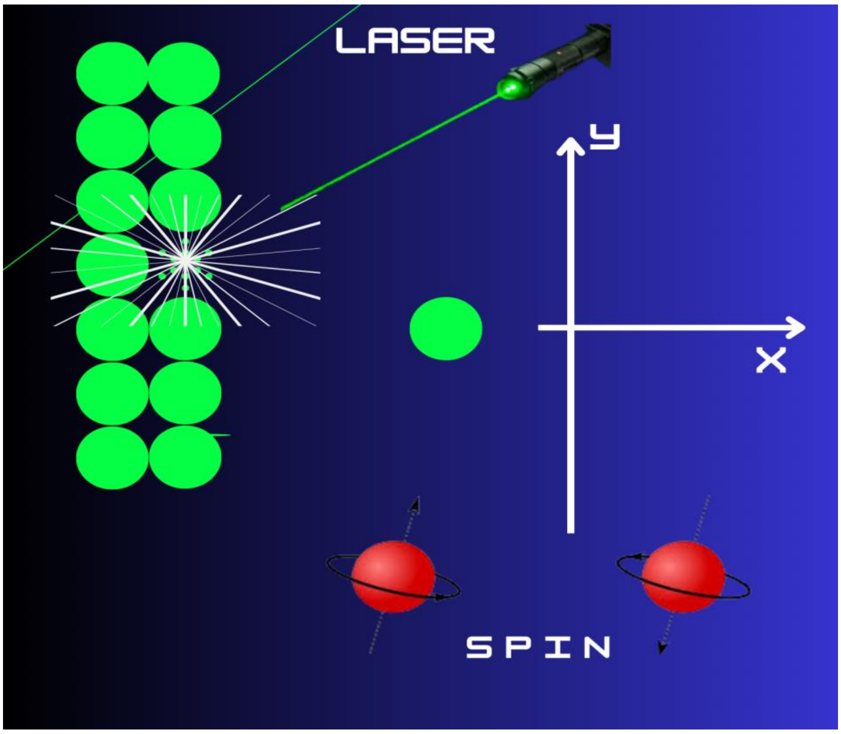

Figure 1: Experimental design for chain dissociation of fullerenes

3-Model and statistical study

● Bonding energy between particles

As we mentioned earlier is composed of 60 carbon atoms, and the energy of the carbon bond is in the range of 3,6 electron volts (ev), which is equivalent to $5.9x10^{-16}$ (mJ).

● The energy required to decompose fullerenes

Assuming that the fullerenes are linked to each other by a carbon bond, this bond, as is known, is estimated at 3.6ev,($5.9x10^{-16}$ (mJ).), and in order to dismantle a chain with an N_b molecule of fullerene, it is necessary to break an N_L carbon bond, according to the following relationship:

$N_b = \frac{NL-1}{3}$ (1)

And out of:

So, there are 10^{12}x2.06 bonds

Only the energy needed is 0.00122 mj where:

N_L: number of bonds

N: number of fullerene globules with N_b=5.78x10^{15} globules

Thus, 10mj breaks 1736 bonds.

● THE INITIAL VELOCITY AT WHICH THE FULLERENE MOLECULE LEAVES THE SURFACE:

After being bombarded with laser beams, the fullerene particles gain kinetic energy, so they set off with an initial velocity that you get when the carbon bond between fullerenes.

$$\frac{1}{2} m {v_0}^2 = E_{c-c}$$

$$v_0 = \sqrt{\frac{2E_{c-c}}{m}}$$

Where:

E_{c_c} : bonding energy

m: fullerene mass estimated: 119.65 10^{-23} g

By substituting to the extent that the initial velocity at which the fullerene's leave the surface is in the range of:

v_0 =986209.778 m/s

● THE FORCES ACTING ON THE PELLETS DURING THE TRANSITION

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To extract the equation of motion for the nanoparticle of fullerene, we studied the forces affecting it withing the electromagnetic field, as we proceeded from Newton's law. The second is the movement. We found that the ball is affected by the force of gravity and the strength of the electromagnetic field, in addition to the stokes force, and it is symbolized by Fs :and its expression is as follows[26-27]:

$$\overrightarrow{F_S} = -6\pi\mu r\vec{v} \qquad (2)$$

Where:
V: falling speed

$$v = \frac{2r^2\, g\Delta(\rho)}{9\mu} \qquad (3)$$

r: the radius of the nanoparticle.
(**ρ**)*Δ*: The difference between the volumetric mass of the pellet and the air
μ: Dynamic viscosity

●MOTION E QUATIONS

In order to extract the equations of motion, we divided the study into two cases:

●The first case: we relied on studying the movement of the fullerene nanoparticle in terms of change in charge.

●The second case: we relied on the study of the bold movement of fullerene in terms of the change in spin.

By projection, we obtained the equation of motion for each of the two cases.

Beginning of:

$$\sum \quad \vec{F} = m\vec{\gamma} \qquad (4)$$

$$q\vec{E} + q\vec{v}\times\vec{B} + m\vec{g} = m\vec{\gamma} \qquad (5)$$

Projecting on the axes of motion, we find:

$$\{ \quad qBv_y = m\gamma_x \qquad (6) \qquad qE - qBv_x + mg = m\gamma_y \qquad (7) \qquad \Rightarrow \{ \gamma_x = \frac{qBv_x}{m} \; \gamma_y = \frac{qE}{m} - \frac{qBv_x}{m} + g$$

Taking into account the initial velocity V_0

Integrating (6) we find:

$$qB_y = m(v_x - v_0) \qquad (8)$$

Integrating (7) we find:

$$qEt - qB_x + mgt = mv_y \qquad (9)$$

We substitute the speed into its value in equation (9)

Where:

$$V_y = \frac{m}{qB}x$$

We find:

$$qEt - qB_x + mgt = \frac{m^2}{qB}\gamma_x \qquad (10)$$

$$qE - qBv_x + mg = u - qB\gamma_x \qquad (11)$$

4-Results and discussion

From equation (10) and (11) we find a non-homogeneous differential equation of the second degree, based on a digital program and after the inclusion of the solution to the differential equation with the fixation of both the values of the electric field and the magnetic field at specific values, and taking into account the previously calculated initial velocity, we get the results shown in the following figures from figure 2 to figure 15.

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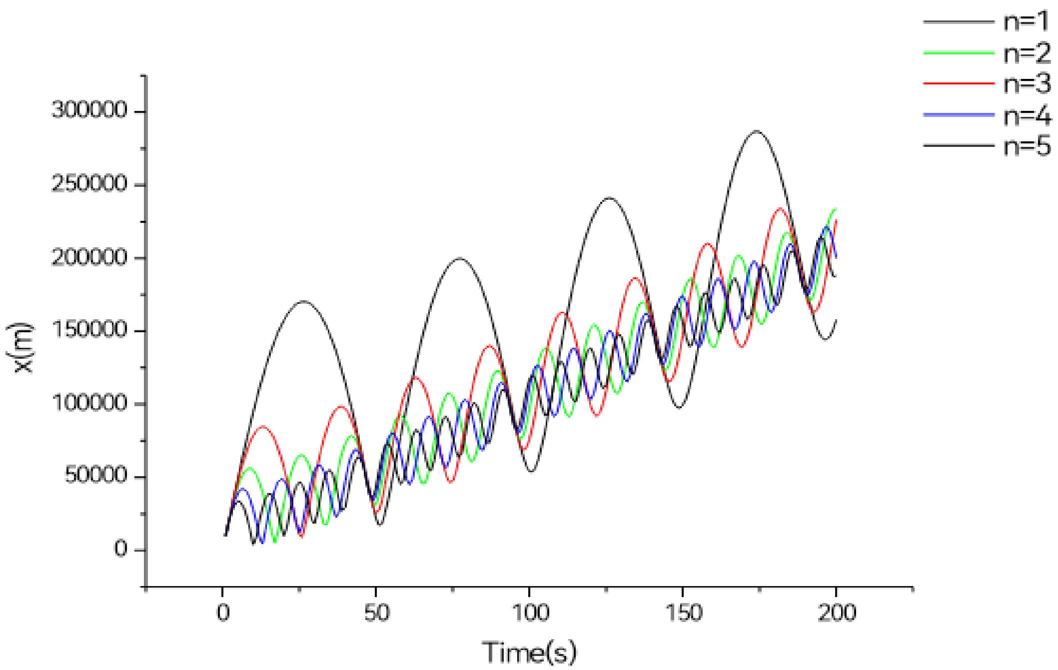

Figure 2: Curve or path of the fullerene molecule during time in term of the change in charge (spin down).

Through the curve, we notice that the maximum and minimum values for the distance are when the lowest value of the charge takes n=1

That is, the greater the charge of fullerene, the lower the value of its maximum speed.

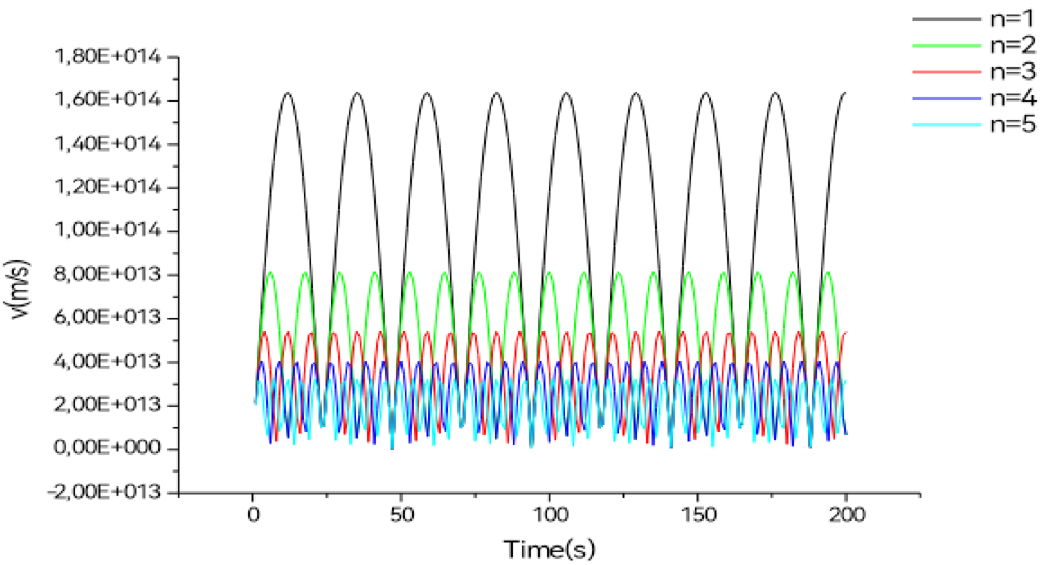

Figure 3: A curve representing the velocity of a fullerene nanoparticle over time in time in terms of charge (spin down).

The speed takes its maximum value when the charge takes its lowest value, n=1, and it takes its minimum value when the charge takes its largest value, n=5. That is, the higher the charge of the fullerene, the lower its velocity value.

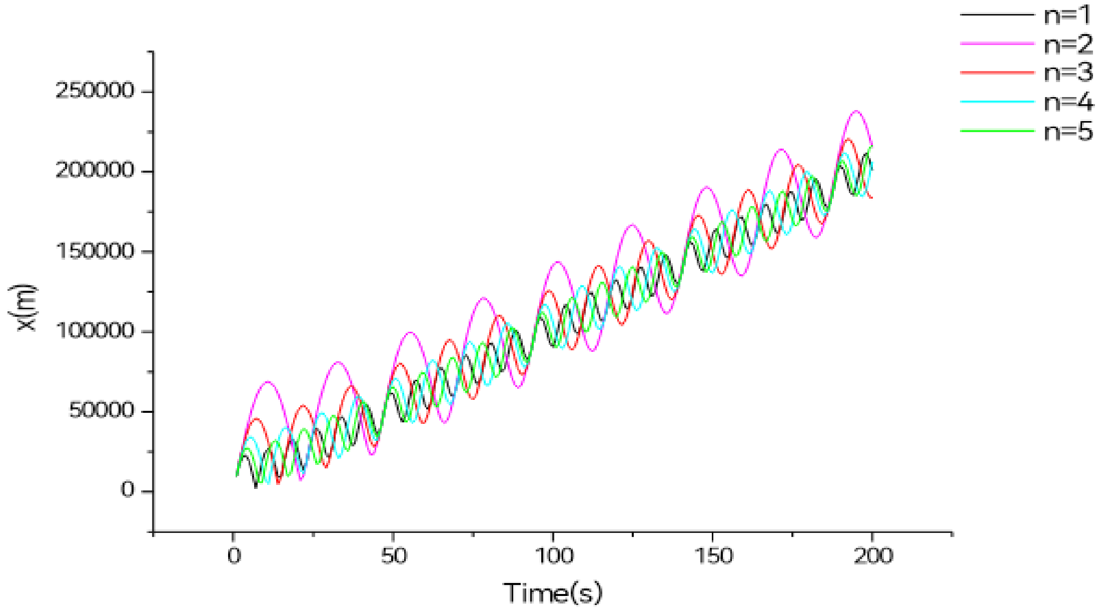

Figure 4: A curve representing the trajectory of the fullerene molecule through time in terms of charge(spin up).

When we have spin up, we notice that the maximum values for the distance are when the charge takes the value n=2.

We also notice that the higher the charge ,the lower the skeletal values of movement.

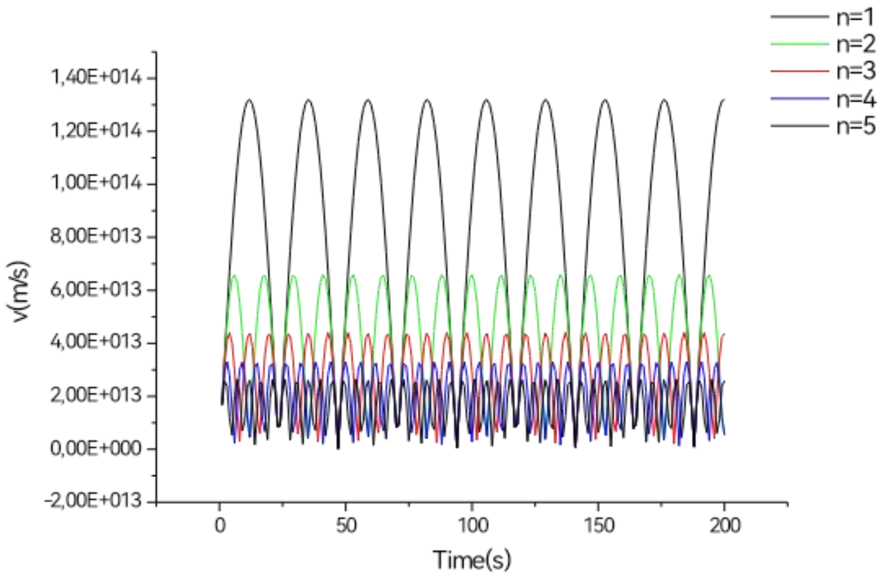

Figure 5: A curve representing the change in the velocity of the fullerene molecule during time in terms of the change in charge (spin up)

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In this case, the speed takes its maximum value when the charge takes its lowest value, n=1, and on the other hand, it takes its minimum value when the charge takes its largest value n =5. That is, the greater the charge, the lower the maximum velocity values.

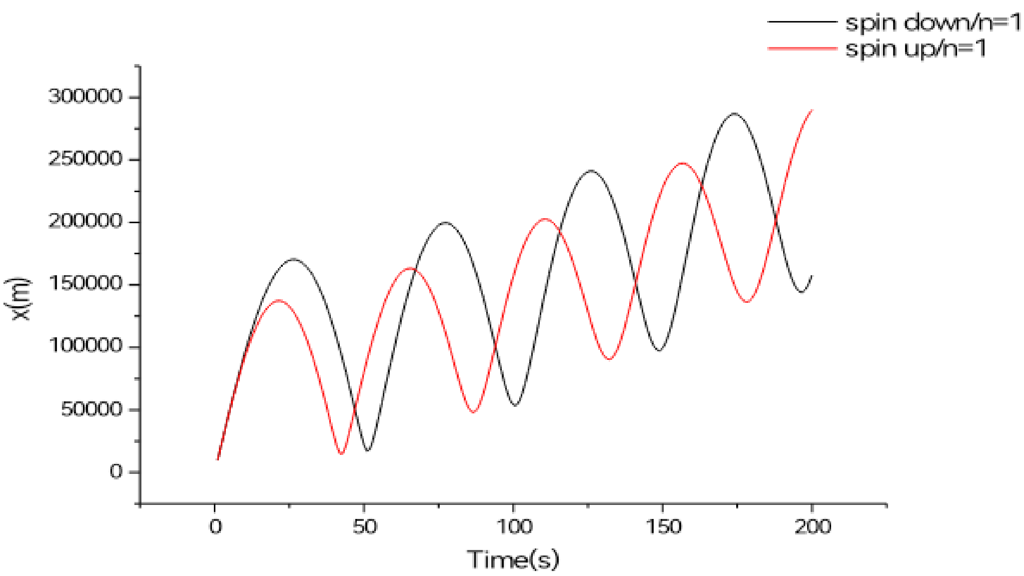

Figure 6 : A curve representing the trajectory of a fullerene molecule through time in terms of change in spin

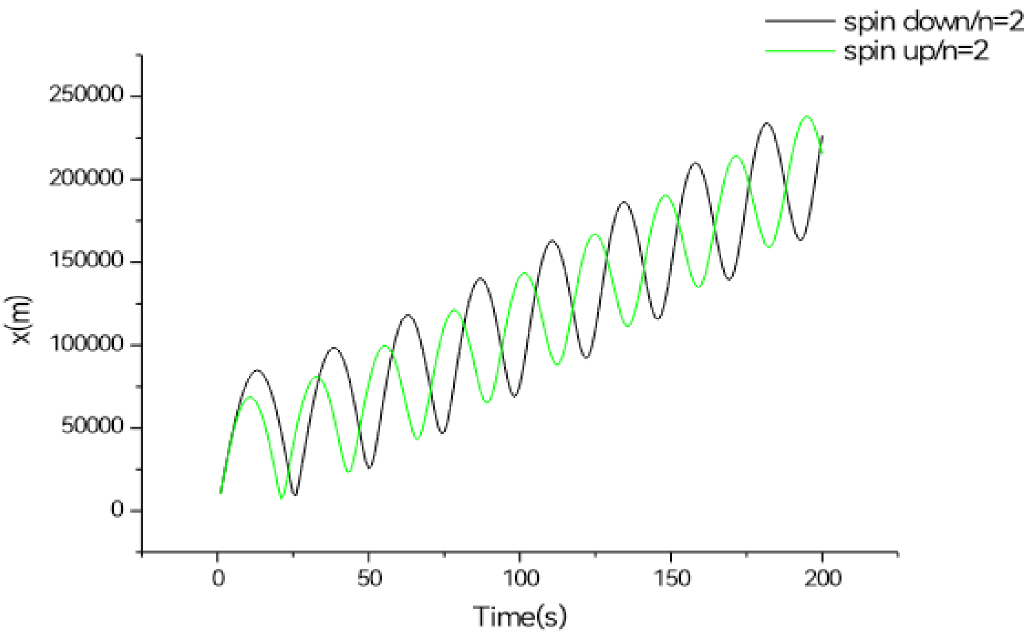

Figure 7: A curve representing the trajectory of the fullerene molecule through time in terms of the change in spin

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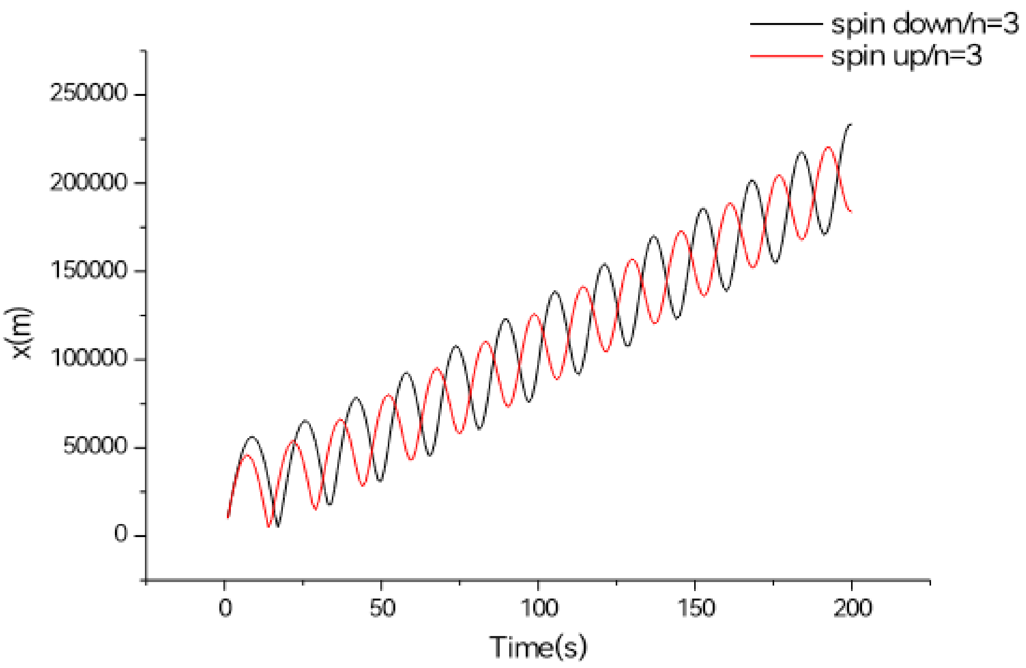

Figure 8: A curve representing the trajectory of the fullerene molecule through time in terms of the change in spin

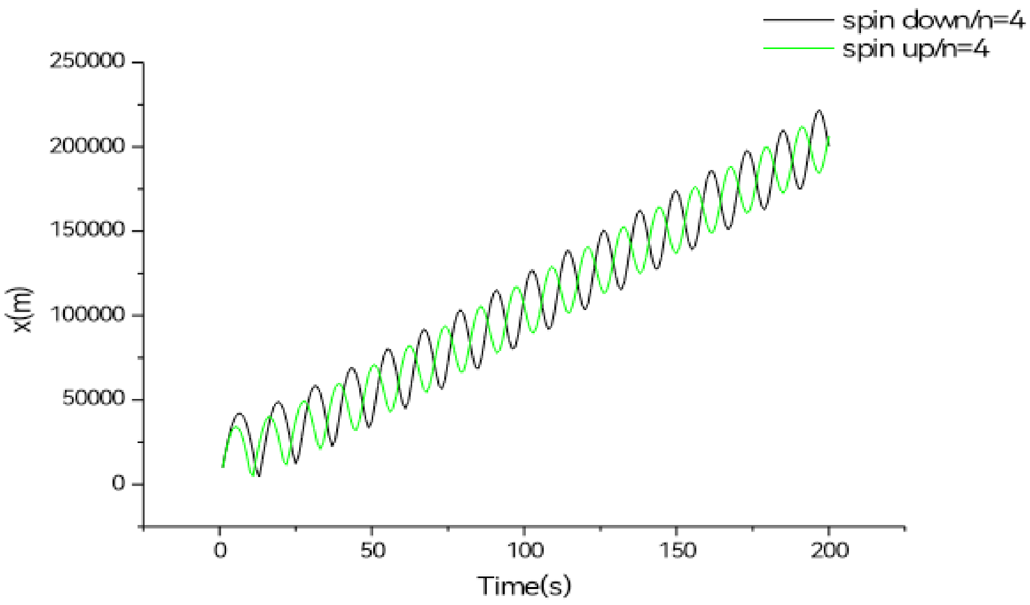

Figure 9: A curve representing the trajectory of the fullerene molecule through time in terms of the change in spin

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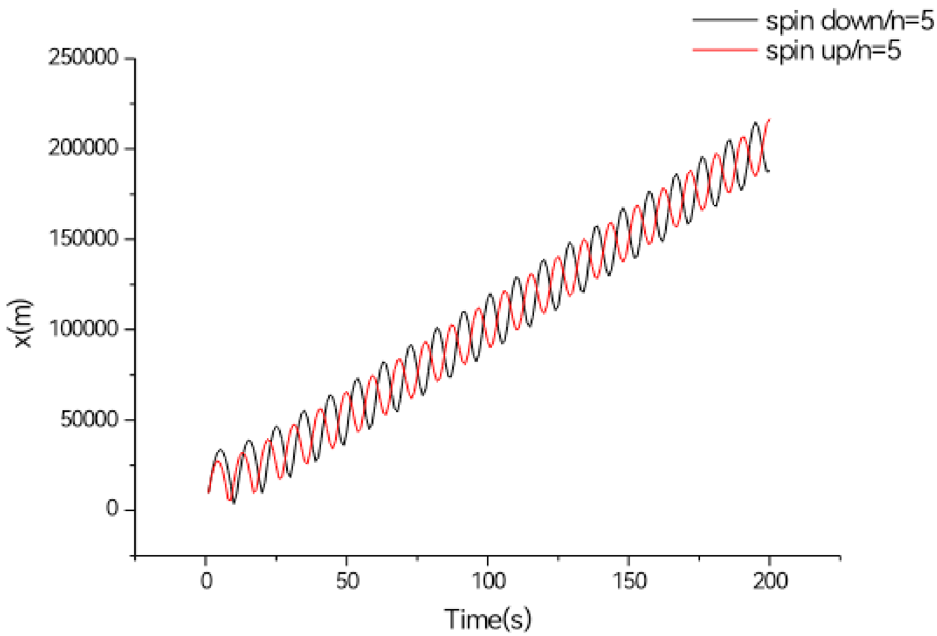

Figure 10: Is a curve representing the trajectory of a fullerene molecule through time in terms of change in spin

Based on figures 6, 7, 8, 9, 10 and when comparing the trajectory of the molecule in terms of the change in spin, we notice that the distance takes its greatest values when we have (spin down), and in return it takes its minimum values when spin (up).

On the other hand, we notice that the fullerene molecules charged with electrons with a lower spin have a longer path than the fullerene molecules charged with electrons with an upper spin

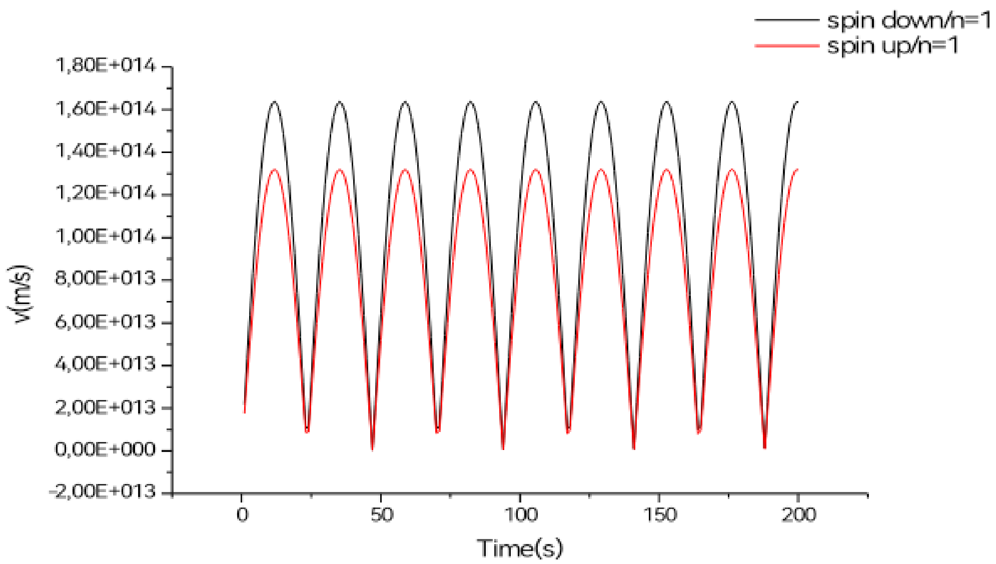

Figure 11: A curve representing the change in the velocity of the fullerene molecule through time in terms of the change in spin

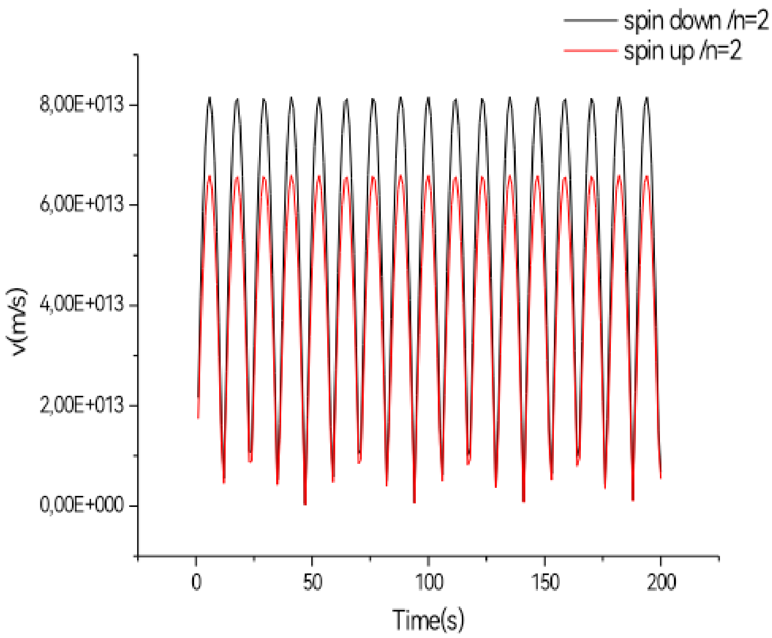

Figure12: A curve representing the change in the velocity of the fullerene molecule through time in terms of the change in spin

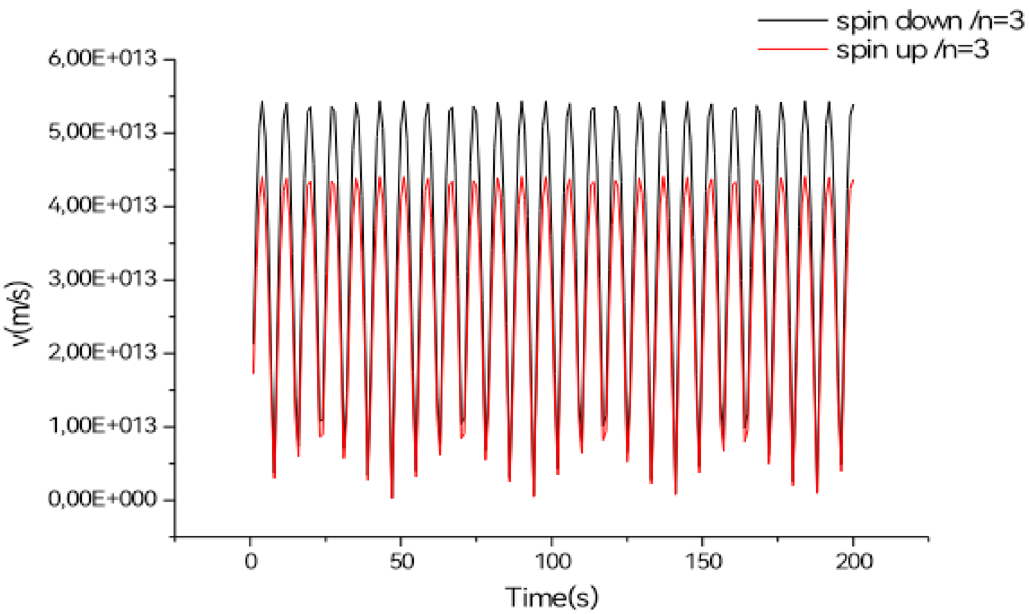

Figure 13: A curve representing the change in the velocity of the fullerene molecule through time in terms of the change in spin

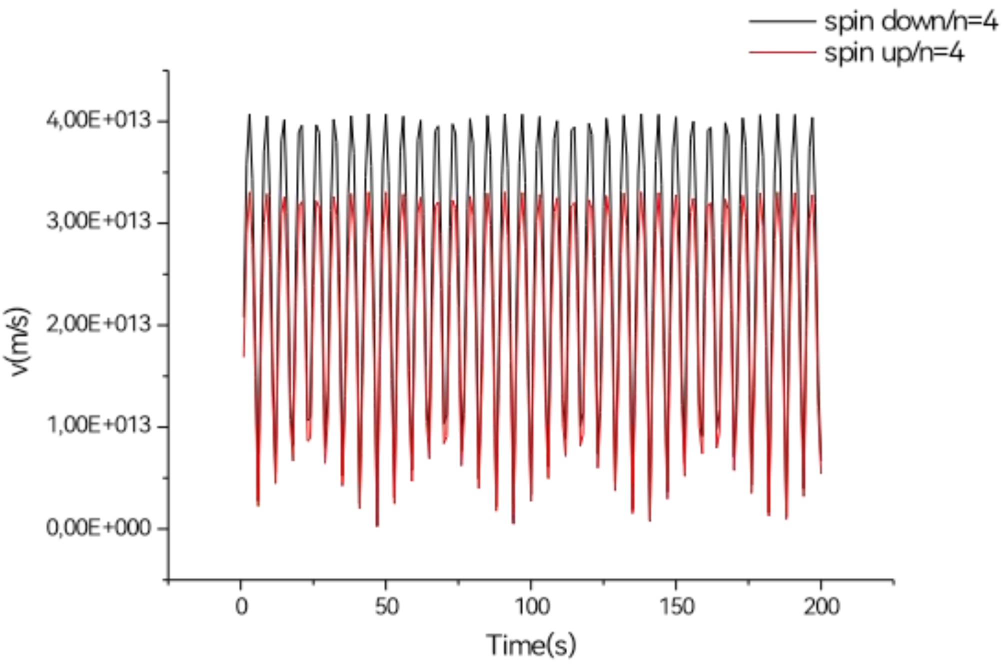

Figure 14: A curve representing the change in the velocity of the fullerene molecule through time in terms of the change in spin

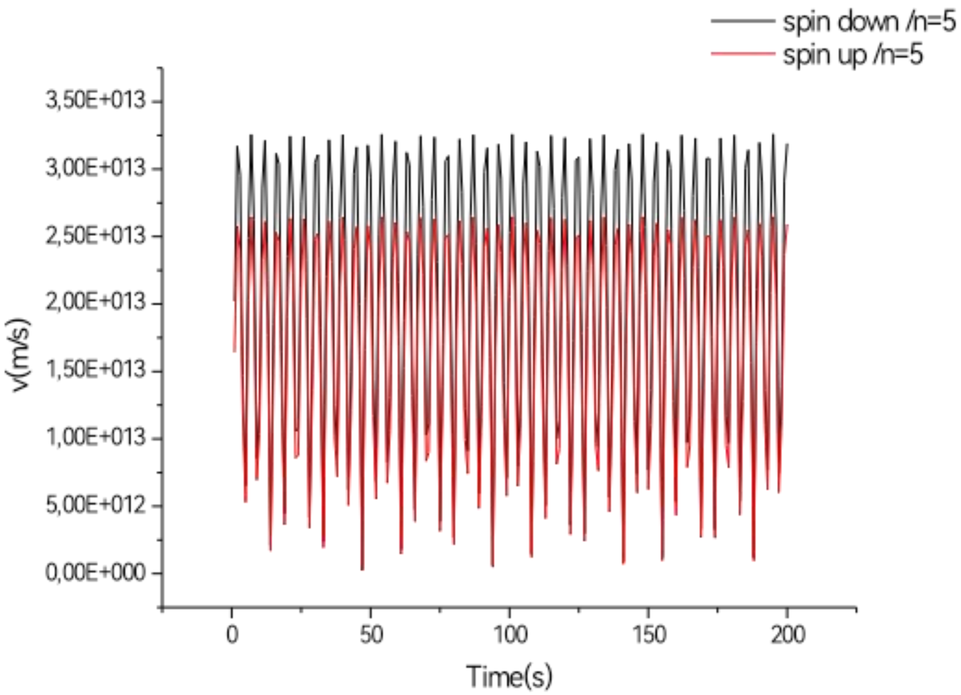

Figure 15: A curve representing the change in the velocity of the fullerene molecule through time in terms of the change in spin

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Figures 11, 12,13,14,15 when comparing the change in the speed of the fullerene molecule in terms of the change in spin, we notice that is the speed taken from its maximum values when we have (spin down), and in return it takes its minimum values when (spin up). we can also say that the fullerene molecules charged with electrons with a lower spin are faster than the fullerene molecules charged with electrons with an upper spin.

5-Conclusion

Through this work, we were able to study the movement of the fullerene molecule charged with electrons with a specific spin, where after analyzing the results obtained, we have come to the conclusion that:

- Fullerene's decrease their trajectory and their maximum velocity decreases as their charge increases and regardless of whether the spin is upper or lower.
- Fullerene molecules charged with electrons, whether with a lower spin or with an upper spin, their path length decrease as their charge increase.
- Electron_ charged fullerene molecules, whether with a lower spin or with an upper spin, move their maximum speed as their scarcity increases.
- Fullerene molecules charged with lower spin electrons have a longer path than fullerene molecules charged with upper spin electrons.
- Fullerene molecules charged with lower spin electrons are faster than fullerene molecules charged with upper spin electrons.

These important results will be used in future applications of matter teleportation.

References

1. PRINZ, Gary A. Magnetoelectronics. *Science*, 1998, vol. 282, no 5394, p. 1660-1663.
2. ŽUTIĆ, Igor, FABIAN, Jaroslav, et SARMA, S. Das. Spintronics: Fundamentals and applications. *Reviews of modern physics*, 2004, vol. 76, no 2, p. 323.
3. WOLF, S. A., AWSCHALOM, D. D., BUHRMAN, R. A., *et al.* Spintronics: a spin-based electronics vision for the future. *science*, 2001, vol. 294, no 5546, p. 1488-1495.
4. HAN, Wei, KAWAKAMI, Roland K., GMITRA, Martin, *et al.* Graphene spintronics. *Nature nanotechnology*, 2014, vol. 9, no 10, p. 794-807.
5. PEARTON, S. J., NORTON, D. P., FRAZIER, R., *et al.* Spintronics device concepts. *IEE Proceedings-Circuits, Devices and Systems*, 2005, vol. 152, no 4, p. 312-322.
6. FELSER, Claudia et FECHER, Gerhard H. (ed.). *Spintronics: from materials to devices*. Springer Science & Business Media, 2013.
7. ZHAO, Weisheng et PRENAT, Guillaume (ed.). *Spintronics-based computing*. Berlin, Germany: Springer, 2015.
8. YAKOUT, Saad Mabrouk. Spintronics: future technology for new data storage and communication devices. *Journal of superconductivity and novel magnetism*, 2020, vol. 33, no 9, p. 2557-2580.
9. LIM, Byeonghwa, HU, Xinghao, TORATI, Sri Ramulu, *et al.* Spintronics Devices for Bio-medical Applications. In: *Proceedings of the Korean Magnestics Society Conference*. The Korean Magnetics Society, 2017. p. 28-29.
10. ROY, Kuntal, BANDYOPADHYAY, Supriyo, et ATULASIMHA, Jayasimha. Hybrid spintronics and straintronics: A magnetic technology for ultra-low energy computing and signal processing. *Applied Physics Letters*, 2011, vol. 99, no 6, p. 063108.
11. KANG, Seung H. Recent advances in spintronics for emerging memory devices. *JOM*, 2008, vol. 60, p. 28-33.
12. ZABEL, Hartmut. Progress in spintronics. *Superlattices and microstructures*, 2009, vol. 46, no 4, p. 541-553.
13. DIETL, Tomasz, AWSCHALOM, David D., KAMINSKA, Maria, *et al.* (ed.). *Spintronics*. Academic Press, 2009.
14. PEARTON, Stephen J., ABERNATHY, Cammy R., et REN, Fan. *Gallium nitride processing for electronics, sensors and spintronics*. Springer Science & Business Media, 2006.
15. NASIRPOURI, Farzad et NOGARET, Alain (ed.). *Nanomagnetism and spintronics: fabrication, materials, characterization and applications*. World Scientific, 2010.
16. IVANOV, V. A., AMINOV, T. G., NOVOTORTSEV, V. M., *et al.* Spintronics and spintronics materials. *Russian Chemical Bulletin*, 2004, vol. 53, p. 2357-2405.
17. WOLF, Stuart A., CHTCHELKANOVA, Almadena Yu, et TREGER, Daryl M. Spintronics—A retrospective and perspective. *IBM journal of research and development*, 2006, vol. 50, no 1, p. 101-110.
18. GUPTA, Anshu, SILOTIA, Harsha, KUMARI, Anamika, *et al.* KTaO3—the new kid on the spintronics block. *Advanced Materials*, 2022, vol. 34, no 9, p. 2106481.
19. YAKOUT, Saad Mabrouk. Spintronics: future technology for new data storage and communication devices. *Journal of superconductivity and novel magnetism*, 2020, vol. 33, no 9, p. 2557-2580.
20. HE, Qing Lin, HUGHES, Taylor L., ARMITAGE, N. Peter, *et al.* Topological spintronics and magnetoelectronics. *Nature materials*, 2022, vol. 21, no 1, p. 15-23.

Journal of Chemical Health Risks
www.jchr.org
JCHR (2023) 13(4), 1499-1510 | ISSN:2251-6727

21. SHAKIL, M., KOUSAR, Memoona, GILLANI, S. S. A., *et al.* First principal computation of half metallicity and mechanical properties of a new series of half Heusler alloys KMnZ (Z= B, Si, Ge, As) for spintronics. *Indian Journal of Physics*, 2022, vol. 96, p. 115-126.
22. HOSSAIN, Mongur, QIN, Biao, LI, Bo, *et al.* Synthesis, characterization, properties and applications of two-dimensional magnetic materials. *Nano Today*, 2022, vol. 42, p. 101338.
23. TAN, Yuan-Zhi, XIE, Su-Yuan, HUANG, Rong-Bin, *et al.* The stabilization of fused-pentagon fullerene molecules. *Nature chemistry*, 2009, vol. 1, no 6, p. 450-460.
24. SHEKA, E. F. "Chemical portrait" of fullerene molecules. *Journal of Structural Chemistry*, 2006, vol. 47, p. 593-599.
25. GOEL, Anish, HOWARD, Jack B., et VANDER SANDE, John B. Size analysis of single fullerene molecules by electron microscopy. *Carbon*, 2004, vol. 42, no 10, p. 1907-1915.
26. VOLGIN, Igor V., LARIN, Sergey V., ABAD, Enrique, *et al.* Molecular dynamics simulations of fullerene diffusion in polymer melts. *Macromolecules*, 2017, vol. 50, no 5, p. 2207-2218
27. WANG, Yonggang, LI, Yusong, et PENNELL, Kurt D. Influence of electrolyte species and concentration on the aggregation and transport of fullerene nanoparticles in quartz sands. *Environmental Toxicology and Chemistry: An International Journal*, 2008, vol. 27, no 9, p. 1860-1867.