

The Cause of Brownian Motion

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Abstract

Brownian motion of small particles has been observed and studied in the past 200 years due to its significance in comprehending physics at the microscopic scale. However, the mechanism that causes Brownian motion remains unclear. Albert Einstein statistically modeled the behavior of the particles moving without knowing why they were moved. It was postulated that the particles in Brownian motion are pushed by molecules. However, this study has proven that the random movement of molecules cannot provide sufficient momentum to drive Brownian motion. Instead, we propose that Brownian motion is driven by transimpact – an interaction between molecules and a side effect of atomic electron transition. The impact of electron orbital transition to adjacent particles is explosive, pushing adjacent particles or objects apart. Indeed, transimpact might be a common interaction behind many physical phenomena, such as electron orbital perturbation, molecular vibration/random motion, phase transition, photoelectric effect, Brownian motion, and the rotation of Crookes radiometers. These findings also pose a challenge to the conventional definition of temperature as a representation of the average kinetic energy in a system. There is no such thermometer that can directly measure the average vibration of molecules in a system. Most thermometers, such as infrared thermometers, directly or indirectly detect the emission level of a system, which is primarily determined by the potential energy in the system. Transimpact also enables the exchange of internal energy between the potential and kinetic energy in a system, therefore maintaining the two forms of energy at a certain ratio. This explains the correlation between the temperature and kinetic energy of a system.

Introduction

In 1827, while studying the pollen grains of the plant *Clarkia pulchella* suspended in water under a microscope, Robert Brown observed the jittery motion of minute particles ejected by the pollen grains.^[1-5] By repeating the experiment with particles of inorganic matter, he was able to rule out that the motion was life-related. This motion was later named after him, the Brownian motion. Since then, it has been noticed that Brownian motion is not unique to pollen but is a common phenomenon observable in daily life. Most people might have noticed dust particles dancing in a beam of light in a dark room. It might be an ordinary interaction of fundamental physics.

In 1905, Albert Einstein statistically modeled how the particles move in Brownian motion,^[6-7] which was presented as a way to indirectly confirm the existence of atoms and molecules. The concept of atoms and molecules was not well established back then. Without a full comprehension of why the particles move, it was postulated that the particles in Brownian motion are pushed by the random movement of fluid molecules. However, the underlying physics governing this motion remains unclear to this day. Can the randomly moving molecules have sufficient momentum to drive the pollen for Brownian motion? If not, what is the force that pushes the particles in Brownian motion? These questions may relate to some of the

fundamental processes underlying thermodynamics and many other physics phenomena, which is the primary motivation of this study.

Insufficient Momentum from Molecule Movement

To determine the speed requirement for molecules to drive Brownian motion, let us consider a pollen grain initially at rest. It is struck by a water molecule moving at speed v . To be conservative, let's assume the water molecule is bounced back at the same speed in the opposite direction after the collision, and the pollen picks up a speed of 1 mm/s or 0.001 m/s . The weight of a water molecule is about $2.99 \times 10^{-26} \text{ kg}$. The momentum change of the water molecule after the collision is $v \times 2 \times 2.99 \times 10^{-26} \text{ kg}$ or $v \times 5.98 \times 10^{-26} \text{ kg}$.

The diameter of pollen ranges between 1×10^{-5} and $1 \times 10^{-4} \text{ m}$. The size of *Clarkia pulchella* pollen is actually in the higher range. To be conservative, let's take the lower bound, which corresponds to a volume of $5.24 \times 10^{-16} \text{ m}^3$. Since the pollen grains are suspended in the water, their density must be equal to or greater than water. Let's also take the lower bound, i.e., $1,000 \text{ kg/m}^3$. Thus, the pollen grain gains a momentum of $5.24 \times 10^{-16} \text{ kg}\cdot\text{m/s}$ from the collision. This momentum should equal the momentum change of the water molecule. Hence,

$$(1) \quad v \times 5.98 \times 10^{-26} = 5.24 \times 10^{-16}.$$

So, in order to push the pollen at a speed of 1 mm/s , the speed of the water molecule must be greater than

$$(2) \quad v = 8.76 \times 10^9 \text{ m/s}.$$

This speed is 20 times greater than the speed of light (about $3 \times 10^8 \text{ m/s}$), which is impossible.

One might want to speculate that the collective impacts of multiple water molecules at the same time may be able to push the pollen. Due to the random nature of the collisions, multiple molecules typically come from different directions and tend to cancel each other out. There is a very slim chance that multiple water molecules strike at the pollen on the same surface from the same direction and at the same time.

To estimate this collective probability, let's assume the average speed of water molecules to be $2,000 \text{ m/s}$. This is a very aggressive assumption because the average speed of air molecules is less than $1,200 \text{ m/s}$ and the viscosity of water is much higher than air. Thus, to push the pollen at a speed of 1 mm/s , we would need more than 4.38×10^7 ($8.76 \times 10^9 / 2,000$) water molecules coming from the same direction at the same time.

To comprehend the odds of this collective interaction, let's assume there are 4.38×10^7 water molecules on one side of a pollen grain and the same amount of water molecules on the other side. They can move either toward the pollen or away from it. Each water molecule may randomly flip its direction every second. To push the pollen jiggling at a speed of 1 mm/s , all the water molecules on one side of the pollen must travel toward the pollen, while the water molecules on the other side move away from the pollen simultaneously. The probability of this synchronized activity will be:

$$(3) \quad p = \left(\frac{1}{2}\right)^{4.38 \times 10^7} \times \left(\frac{1}{2}\right)^{4.38 \times 10^7} = \left(\frac{1}{2}\right)^{8.76 \times 10^7} = \frac{1}{10^{2.6 \times 10^7}}$$

It means that this synchronized activity may occur roughly once per year on average. In other words, the pollen would jiggle once per year, which is much longer than the observations. If the movement of molecules cannot provide sufficient momentum for Brownian motion, what mechanism drives Brownian motion?

The Mechanism Driving Brownian Motion

"Transimpact", a term coined from "transition impact," is an interaction between molecules due to a side effect of an atomic electron transition.^[8] Attraction forces are typically induced between molecules in close proximities. When the spacing between molecules becomes too small, the repulsion of the valence electrons between molecules increases rapidly. At a certain distance, the repulsion and attraction strike a balance. This balance is often disrupted by atomic electron transition. Upon absorption of some energy, such as photons, an electron in an atom may excite and jump to a higher orbital, typically in a few nanoseconds.^[9-10] As a consequence, the electron cloud and the volume of the atom/molecule expand and the distance between adjacent molecules reduces. The sudden reduction of molecular spacing breaks the balance between the molecules and increases the repulsion between them. The impact is explosive and may exert a significant force on adjacent molecules.

As illustrated in Figure 1A, two single-atom molecules are positioned next to each other balanced at a small separation. On absorbing energy, one of the molecules undergoes an orbital transition, which increases the molecule's size and reduces the spacing between them, as shown in Figure 1B. Both processes increase the repulsion between them, and the molecules are pushed apart and move in opposite directions, as depicted in Figure 1C.^[8,11]

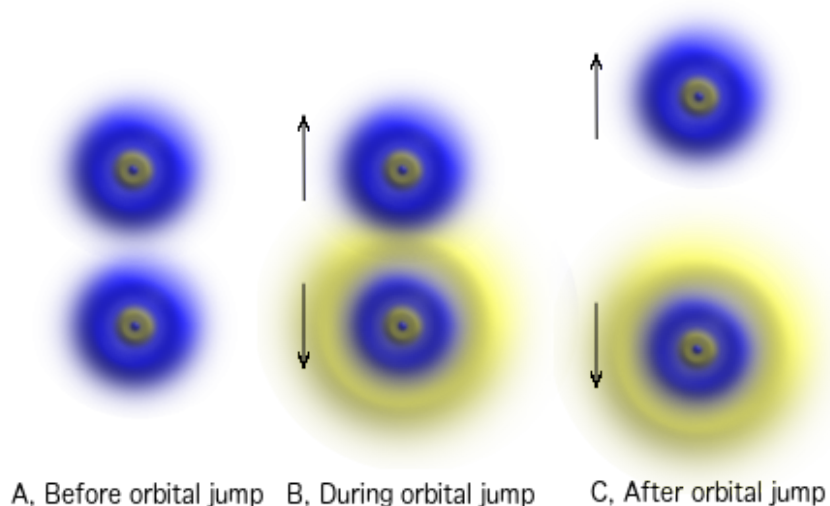


Figure 1, Process of transimpact.

To comprehend this interaction with a concrete example, let us examine the electron orbital transition of an oxygen atom. An oxygen atom has 8 electrons, with a ground state configuration of $1s^2 2s^2 2p^4$. The radius of the atom is primarily

determined by the valence orbital and is approximately 48 pm . The configuration of a typical excited state is $1s^2 2s^2 2p^3 3s^1$. The radius is around 118 pm . Thus, when an oxygen atom becomes excited, its radius more than doubles, resulting in a volume increase of over $1,200\%$ within a period of a few nanoseconds. This expansion effect should be more significant when an orbital transition occurs in a hydrogen atom. This is a very rough estimate just to provide a sense of how a water molecule could expand significantly as it absorbs energy from the ambient.

The impact of a transimpact may be envisioned with the burst of popcorn. Imagine the momentum exerted on adjacent objects by the popcorn as it bursts on the heating pane. This analogy is similar to the interaction when an electron in a water molecule becomes excited next to a pollen grain, which is believed to be the mechanism driving the Brownian motion of the pollen in water.

Transimpact – a Common Interaction

Transimpact may be an ordinary and fundamental interaction that influences many aspects of physical processes. The particles or objects being pushed in transimpacts can be other molecules, dust particles, pollen, or even the wall of a container. When a transimpact occurs between two molecules, the molecules are pushed apart while picking up some kinetic energy in the form of vibration in solids or random motion in fluids. As temperature rises, electrons are the first components in a system to absorb and store the energy as the potential in the electrons at higher orbitals. As a side effect of orbital transitions, some of the absorbed energy is transformed into the kinetic energy of the system through transimpacts.^[8] This is why the temperature correlates to the kinetic energy of a system to a certain extent.

With enough energy, electrons may even be ejected from atoms, such as in the photoelectric effect. Albert Einstein showed that the maximum kinetic energy of the ejected electrons is proportional to the extra energy of the incident photons above a certain threshold.^[12] In other words, part of the incident energy is used to remove the electrons from their orbitals, while the rest of the energy is contributed to the momentum of the ejected electrons. Photoelectric effects may be considered as extreme cases of transimpact. In both normal atom electron transition and the photoelectric effect, transimpact plays a significant role in transforming energy between different forms.

Because a nucleus is more than $1,000$ magnitudes heavier than its electrons, most of the vibrations due to transimpacts are observed at electrons. This may explain why electrons orbit in clouds, instead of having well-defined orbits as celestial bodies do. Transimpact also provides the mechanism to drive the Crookes radiometers.^[11] As a transimpact occurs between an air molecule and the vane of a radiometer, the vane is impacted by the impact. When subjected to an intensive light source, the black side of the vanes absorbs the energy more effectively and results in a higher level of transimpacts than the white side. The unbalanced impacts push the vanes to rotate. Additionally, transimpact also plays an important role during phase transitions.^[8] Transimpacts are much more significant than the vibration of molecules. Molecules in solids and fluids are shattered apart by transimpacts, resulting in phase transitions for melting and vaporization.

Misconception about Temperature

Can temperature represent the average kinetic energy of a system? The understanding of transimpact and related findings also pose a challenge to the traditional definition or concept of temperature. As demonstrated above, the change in kinetic

energy of a system is due to transimpacts and the transimpact level of the system relates directly to potential energy in the system. After absorbing ambient energy, such as the specific heat, an electron is excited and jumps to a higher orbital. Part of the absorbed energy is stored by the electron as the orbital energy, which is the sum of the potential energy with respect to the attraction of its host nucleus and the kinetic energy of the electron's orbital motion, as shown in Figure 2B. With each orbital jump, transimpact also transfers some of the energy into kinetic energy to adjacent molecules or objects in the form of particle vibration. As the spacing between molecules expands, the potential energy of molecular and intermolecular bonds also rises. Therefore, transimpact plays a crucial role in transforming energy between different forms, where kinetic energy is just one of them.

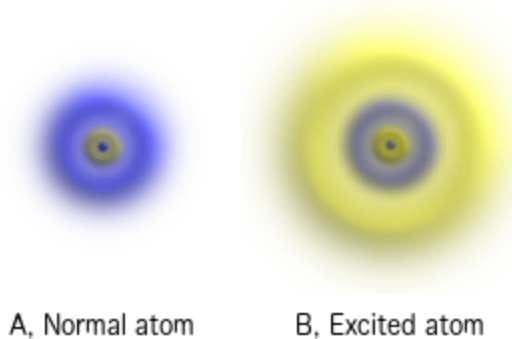


Figure 2, Orbital energy stored by electrons at high orbitals.

With this comprehension, it becomes easy to understand why there is a discrepancy between the measured specific heat and the value predicted from the kinetic theory of gases. The measured specific heat of air (typically $1,005 \text{ J/kg.K}$) is much greater than the predicted value based on the kinetic theory of gases (431 J/kg.K).^[13] This discrepancy arises from the misconception about the temperature that correlates the temperature directly with the kinetic energy of molecule vibration in ideal gases. In reality, there are six different forms of internal energy in a system.^[8] The measured specific heat contributes to the increase in the total thermodynamic energy of a system, and the kinetic energy is just one form of internal energy. Of the measured specific heat for air, 431 J/kg.K of energy is transformed into the kinetic energy of the system, and the rest of the energy is converted and stored in other forms, including the bond energy and the orbital energy in electrons at higher orbitals.

In the context of the specific heat discussed above, the temperature is still partially related to the change in the kinetic energy of a system. However, in the context of latent heat, the change in kinetic energy of the system is completely decoupled from the temperature. During a phase transition, such as ice to water transition, the latent heat added to a system is consumed to break the bonds between molecules. As molecules are freed from solid bonds, their kinetic energy is escalated. However, the temperature of the system remains the same.

Due to the attraction from nuclei, excited electrons in higher orbitals tend to retreat or transition to lower orbitals whenever open spots or electron holes are available. As these electrons transition to lower orbitals, the stored orbital energy is released by emitting photons, which are the heat radiation or thermal energy measured by most thermometers. The temperature readings from the thermometers indicate the calibrated value for the measurements of the emission level from the target objects. In other words, the temperature typically represents the average electron orbital energy level of the

target object, not directly related to the average kinetic energy of molecule vibration. Ideally, temperature should represent the total internal energy of a system.

In the reverse direction of transimpact, there is impactrans, a mechanism that transforms kinetic energy into other forms of energy.^[8] As ambient temperature decreases, a system emits more energy than absorption. As equilibrium shifts to lower levels, more electrons transition to lower orbitals. The average emission level of the system decreases, and so does the temperature measurement of the system. The kinetic energy of the system should eventually decrease through impactrans, where the energy is transformed into potential energy, such as electron orbital energy, and is eventually emitted. Thus, transimpact and impactrans maintain different forms of energy at a certain ratio in a system, enabling the kinetic energy to trace the change of the potential energy in the system. Hence, temperature can serve as a partial indicator of a system's total internal energy, but it loses this capacity during a phase transition at a constant temperature. This explains the certain correlation between temperature and the kinetic energy of a system, which many classical theories, such as the ideal gas law and the dynamic theory of gases, rely on. Now, we know that this correlation is an indirect and secondary relationship.

Conclusions

Transimpact is the mechanism behind many physical interactions and phenomena, such as the perturbation of electrons in orbital clouds, the vibration of molecules in solids, the random movement of molecules in fluids, the Brownian motion of small particles, the rotation of Crookes radiometers, the photoelectric effect, and phase transition to name just a few. The random moving molecules cannot drive Brownian motion. Instead, Brownian motion is due to transimpact, a side effect of atomic electron transition. In other words, the random motion of molecules is not the cause of Brownian motion, but a result of transimpact. In addition to kinetic energy, there are also several other forms of energy in a system. Temperature is typically a measurement of the average orbital energy level in a system, not the kinetic energy of the system. Different forms of energy can be exchanged through transimpact and impactrans to maintain a certain ratio in a system. Therefore, temperature relates to the kinetic energy of a system to a certain extent.

See Also

- [Unified Theory of Low and High-Temperature Superconductivity \(PDF\)](#)
- [Superfluids Are Not Fluids \(PDF\)](#)
- [Electron Tunnel \(PDF\)](#)
- [LK-99 Limitations and Significances \(PDF\) \(中文\)](#)
- [The Cause of Brownian Motion \(PDF\)](#)
- [The Process Driving Crookes Radiometers \(PDF\)](#)
- [Can Temperature Represent Average Kinetic Energy? \(PDF\)](#)
- [Why Phase Transition Temperature Remains Constant \(PDF\)](#)
- [Is Thermal Expansion Due to Particle Vibrating? \(PDF\)](#)
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Revision History

- [06/16/2019: Initial Post of This Article.](#)
- [06/03/2021: Revision for Grammar Check.](#)
- [01/07/2023: Adding More Evidence and Removing Energy Theory Sections.](#)
- [10/01/2023: Revision for Clarity and Section Titles.](#)

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