# Kinematics of Nuclear Reactions

By

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Reaction Kinematics

The one or few nucleon transfer reaction has been a great tool for investigating the single-particle properties of a nucleus. Both stable and exotic beams are utilized to study transfer reactions in normal and inverse kinematics, respectively. Because many energy levels of the heavy recoil from the two-body nuclear reaction can be populated by using a single beam energy, identifying each populated state, which is not often trivial owing to high level-density of the nucleus, is essential.

**Kinematics**, branch of physics and a subdivision of classical mechanics concerned with the geometrically possible motion of a body or system of bodies without consideration of the forces involved (*i.e.*, causes and effects of the motions).

Kinematics aims to provide a description of the spatial position of bodies or systems of material particles, the rate at which the particles are moving (velocity), and the rate at which their velocity is changing (acceleration). When the causative forces are disregarded, motion descriptions are possible only for particles having constrained motion—*i.e.*, moving on determinate paths. In unconstrained, or free, motion, the forces determine the shape of the path.

For a particle moving on a straight path, a list of positions and corresponding times would constitute a suitable scheme for describing the motion of the particle. A continuous description would require a mathematical formula expressing position in terms of time.

When a particle moves on a curved path, a description of its position becomes more complicated and requires two or three dimensions. In such cases continuous descriptions in the form of a single graph or mathematical formula are not feasible. The position of a particle moving on a circle, for example, can be described by a rotating radius of the circle, like the spoke of a wheel with one end fixed at the centre of the circle and the other end attached to the particle. The rotating radius is known as a position vector for the particle, and, if the angle between it and a fixed radius is known as a function of time, the magnitude of the velocity and acceleration of the particle can be calculated. Velocity and acceleration, however, have direction as well as magnitude; velocity is always tangent to the path, while acceleration has two components, one tangent to the path and the other perpendicular to the tangent.

Processes that are not Considered to be Nuclear Reactions

In nuclear physics and nuclear chemistry, a **nuclear reaction** is semantically considered to be the process in which two nuclei, or a nucleus and an external subatomic particle, collide to produce one or more new nuclides. Thus, a nuclear reaction must cause a transformation of at least one nuclide to another. If a nucleus interacts with another nucleus or particle and they then separate without changing the nature of any nuclide, the process is simply referred to as a type of nuclear scattering, rather than a nuclear reaction.

In principle, a reaction can involve more than two particles colliding, but because the probability of three or more nuclei to meet at the same time at the same place is much less than for two nuclei, such an event is exceptionally rare. The term "nuclear reaction" may refer either to a change in a nuclide **induced** by collision with another particle, or to a **spontaneous** change of a nuclide without collision.

Natural nuclear reactions occur in the interaction between cosmic rays and matter, and nuclear reactions can be employed artificially to obtain nuclear energy, at an adjustable rate, on demand. Perhaps the most notable nuclear reactions are the nuclear chain reactions in fissionable materials that produce induced nuclear fission, and the various nuclear fusion reactions of light elements that power the energy production of the Sun and stars.

The term 'nuclear reaction' is generally used to refer to the externally induced changes brought on to atomic nuclei. Therefore, the following processes cannot be classified as nuclear reactions:

- Nuclear scattering processes – processes that involve the collision and subsequent separation of atomic nuclei without any notable changes in the nuclear composition. In these processes, only momentum and energy are transferred.

- Nuclear Decay – a process through which an unstable nucleus emits radiation in order to lose energy.

- Spontaneous fission reactions – nuclear fission reactions that do not require a neutron to proceed and are, therefore, not induced.

These processes are quite similar to nuclear reactions (but are spontaneous rather than induced).

Why do Nuclear Reactions Release Tremendous Amounts of Energy?

The mass of an atomic nucleus is always less than the sum of the individual masses of each subatomic particle that constitutes it (protons and neutrons). This difference in mass is attributed to nuclear binding energy (often referred to as a mass defect). Nuclear binding energy can be defined as the energy required to hold all the protons and neutrons within the nucleus.

During a nuclear reaction (such as a fission or fusion reaction), the mass accounted for by the nuclear binding energy is released in accordance with the equation $e = mc^2$ (energy = mass times the square of the speed of light).

To simplify, the products formed in nuclear fission and nuclear fusion always have a lower mass than the reactants. This 'missing' mass is converted into energy. A single gram of matter can release approximately 90,00,00,00,000 kilojoules of energy.

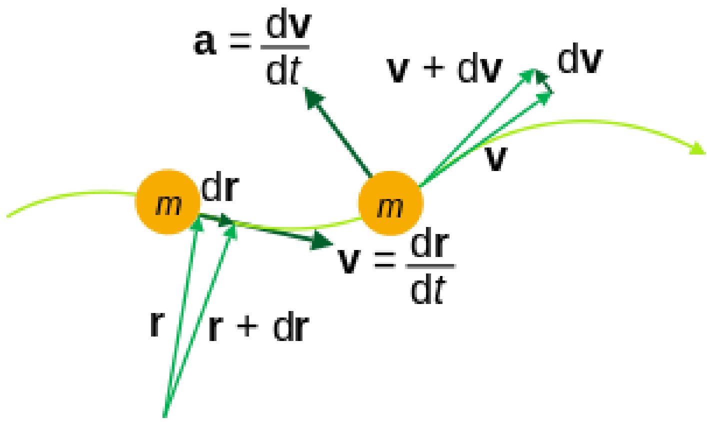
## Kinematics

Kinematics is the branch of classical mechanics that describes the motion of points, objects and systems of groups of objects, without reference to the causes of motion (i.e., forces ). The study of kinematics is often referred to as the "geometry of motion."

Objects are in motion all around us. Everything from a tennis match to a space-probe flyby of the planet Neptune involves motion. When you are resting, your heart moves blood through your veins. Even in inanimate objects there is continuous motion in the vibrations of atoms and molecules. Interesting questions about motion can arise: how long will it take for a space probe to travel to Mars? Where will a football land if thrown at a certain angle? An understanding of motion, however, is also key to understanding other concepts in physics. An understanding of acceleration, for example, is crucial to the study of force.

To describe motion, kinematics studies the trajectories of points, lines and other geometric objects, as well as their differential properties (such as velocity and acceleration). Kinematics is used in astrophysics to describe the motion of celestial bodies and systems; and in mechanical engineering, robotics and biomechanics to describe the motion of systems composed of joined parts (such as an engine, a robotic arm, or the skeleton of the human body).

A formal study of physics begins with kinematics. The word "kinematics" comes from a Greek word "kinesis" meaning motion, and is related to other English words such as "cinema" (movies) and "kinesiology" (the study of human motion). Kinematic analysis is the process of measuring the kinematic quantities used to describe motion. The study of kinematics can be abstracted into purely mathematical expressions, which can be used to calculate various aspects of motion such as velocity, acceleration, displacement, time, and trajectory.




**Kinematics of a particle trajectory**: Kinematic equations can be used to calculate the trajectory of particles or objects. The physical quantities relevant to the motion of a particle include: mass m, position r, velocity v, acceleration a.