

**INTERFACE BETWEEN CHEMISTRY AND GEOPHYSICS IN ASTEROIDS; THE  
MINOR PLANET**

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**ABSTRACT**

An asteroid is a minor planet—an object larger than a meteoroid (thus 1 meter or larger) that is neither a planet nor an identified comet—that orbits within the inner Solar System or is co-orbital with Jupiter (Trojan asteroids). Asteroids are rocky, metallic, or icy bodies with no atmosphere, and are broadly classified into C-type (carbonaceous), M-type (metallic), or S-type (siliceous). The size and shape of asteroids vary significantly, ranging from small rubble piles under a kilometre across to Ceres, a dwarf planet almost 1000 km in diameter. A body is classified as a comet, not an asteroid, if it shows a coma (tail) when warmed by solar radiation, although recent observations suggest a continuum between these types of bodies. Asteroids are a source of precious metals, and base metals for in-space use. Some elements exceed terrestrial ore grades: Ir/Ru/Os/Ni/Pt/Rh/Co/O/Pd/Fe/Mg/Rh/W/Au. Total PGM grades in iron meteorites are lower than previous estimates. Mineral processing can separate refractory metal nuggets and other components.

**KEYWORDS:** Carbonaceous, siliceous, metallic, asteroids, meteor (Ulka), meteorite, meteoroids.

**INTRODUCTION**

Asteroids are rocky, airless remnants left over from the formation of the solar system 4.6 billion years ago, orbiting the Sun primarily within the Main Asteroid Belt between Mars and Jupiter. Numbering over a million, these "minor planets" range from tiny pebbles to Ceres, a nearly 1,000 km wide dwarf planet.

Asteroids are not gas; they are solid, rocky, and metallic bodies, often containing ice. As remnants from the formation of the solar system, they are essentially small, airless, solid "space rocks" that orbit the Sun, primarily located between Mars and Jupiter. They differ from gaseous objects or comets, which develop gas tails near the Sun.<sup>[1-5]</sup>

**Composition:** Mostly rock, metal (nickel/iron), and sometimes clay, rather than gas.

**Structure:** Solid, inactive bodies with no permanent atmosphere.

**Location:** Primarily in the main asteroid belt between Mars and Jupiter.

**Size:** They range from small rubble piles to large, round, dwarf planets like Ceres.

Asteroids frequently pass Earth at varying distances, with Near-Earth Objects (NEOs) defined as coming within 30 million miles (48 million km) of Earth's orbit. While some pass within a few lunar distances (approx. 384,000 km), potentially hazardous asteroids are defined as approaching within 4.6 million miles (7.5 million km).

**Near-Earth Objects (NEOs):** These have orbits bringing them within million km (30 million miles, 48 million km) of Earth.

**Potentially Hazardous (PHAs):** Defined as larger than 460 feet (140 m) and coming within 4.6 million miles (7.5 million km) of Earth's orbit.

Recent Close Approaches: In 2024/2025, asteroids have passed at distances ranging from 1,750 km (very small object) to over 4 million km.

Main Belt Distance: The main asteroid belt is much further away, located 1.2 to 2.2 AU (179.5 to 329 million km) from Earth.

Monitoring: NASA's Centre for Near-Earth Object Studies (CNEOS) tracks these distances to monitor for potential impacts.

Lunar Distance (LD): 1 LD 384,000 km. Many passing asteroids are measured in 0.0x LD.

Astronomical Unit (AU): 1 AU=150 million km.

#### Elements of asteroids

${}_{77}\text{Ir}^{192}$ :	2,	8,	18,	32,	15,	2
[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> 4d <sup>10</sup> 4f <sup>14</sup> 5s <sup>2</sup> 5p <sup>6</sup> 5d <sup>7</sup> 6s <sup>2</sup> ]						
${}_{44}\text{Ru}^{101}$ :	2,	8,	18,	15,	1	[1s <sup>2</sup>
2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>6</sup> 5s <sup>1</sup> 4d <sup>7</sup> 5p <sup>2</sup> ]						
${}_{76}\text{Os}^{190}$ :	2,	8,	18,	32,	14,	2
[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> 4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>6</sup> 4f <sup>14</sup> 5d <sup>6</sup> 6s <sup>2</sup> ]						
${}_{28}\text{Ni}^{58}$ :	2,	8,	16,	2	[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>8</sup> 4s <sup>2</sup> ]	
${}_{78}\text{Pt}^{185}$ :	2,	8,	18,	32,	17,	1
[1s <sup>2</sup> 2s <sup>2</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> 4d <sup>10</sup> 4f <sup>14</sup> 5s <sup>2</sup> 5p <sup>6</sup> 5d <sup>9</sup> 6s <sup>1</sup> ]						
${}_{45}\text{Rh}^{102}$ :	2,	8,	18,	16,	1	[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> 4d <sup>8</sup> 5s <sup>1</sup> ]
${}_{27}\text{Co}^{58}$ :	2,	8,	15,	2	[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>7</sup> 4s <sup>2</sup> ]	
${}_{8}\text{O}^{16}$ :	2,	6	[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>4</sup> ]			
${}_{46}\text{Pd}^{106}$ :	2,	8,	18,	18	[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>6</sup> 4d <sup>10</sup> ]	
${}_{26}\text{Fe}^{56}$ :	2,	8,	14,	2	[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 4s <sup>2</sup> 3d <sup>6</sup> ]	
${}_{12}\text{Mg}^{24}$ :	2,	8,	2	[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> ]		
${}_{45}\text{Rh}^{103}$ :	2,	8,	18,	16,	1	[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> 4d <sup>8</sup> 5s]
${}_{74}\text{W}^{184}$ :	2,	8,	18,	32,	12,	2
[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 4s <sup>2</sup> 3d <sup>10</sup> 4p <sup>6</sup> 5s <sup>2</sup> 4d <sup>10</sup> 5p <sup>6</sup> 4f <sup>14</sup> 5d <sup>4</sup> 6s <sup>2</sup> ]						
${}_{79}\text{Au}^{197}$ :	2,	8,	18,	32,	18,	1
[1s <sup>2</sup> 2s <sup>2</sup> 2p <sup>6</sup> 3s <sup>2</sup> 3p <sup>6</sup> 3d <sup>10</sup> 4s <sup>2</sup> 4p <sup>6</sup> 4d <sup>10</sup> 5s <sup>2</sup> 5p <sup>6</sup> 4f <sup>14</sup> 5d <sup>10</sup> 6s <sup>1</sup> ]						



Figure 1: Asteroids.

Asteroids are primarily composed of silicate rock, metallic iron, and nickel, along with varying amounts of carbon, oxygen, hydrogen, and nitrogen, depending on their type. C-type asteroids are rich in carbon and clay, S-types are stony with metals, and M-types are metallic. They often contain precious metals like gold, platinum, and palladium.

- **Silicates & Rocks:** Oxygen, Silicon are the most common, forming silicate rock, particularly in S-type asteroids.
  - **Metals:** Iron and Nickel, are dominant in M-type metallic asteroids.
  - **Precious/Rare Metals:** Cobalt, Iridium, Palladium, Platinum, Rhodium, Ruthenium, Osmium, Gold, Tungsten, are present, especially in metallic asteroids.
  - **Volatiles & Organics:** Carbon, Hydrogen, Nitrogen, and Sulfur are found in high concentrations within C-type (carbonaceous) asteroids.
  - **Water:** Many asteroids, particularly C-types, contain hydrated minerals.
- Composition by Type

- **C-type (Carbonaceous):** Composed of clay, silicate rocks, organic carbon, and water.
- **S-type (Stony):** Composed of silicate materials and nickel-iron.
- **M-type (Metallic):** Composed of iron and nickel.

These materials are remnants from the formation of the solar system, with composition generally determined by their distance from the Sun.<sup>[6-10]</sup>

Asteroids typically travel through space at average orbital speeds of 17 to 25 km/s [38000-56000 mph]. When impacting Earth, they generally strike at a minimum of 11 km/s (25000 mph) with average impact velocities around 17 km/s (38000 mph), although speeds can reach over 72 km/s (160000 mph) depending on their trajectory and origin.

- Asteroid Belt (Average): 17–25 km/s.
- Earth Impact (Average): ~17 km/s.
- Maximum Impact Speed: Up to ~72 km/s (160,000 mph).



Figure 2: Running asteroids.

- Influencing Factors: Speed depends on the distance from the Sun and the shape of the orbit; closer to the Sun means higher velocity.
- Comparison: Asteroids travel about 3–4 times faster than the International Space Station.

Asteroids are rocky, airless remnants left over from the formation of the solar system 4.6 billion years ago, orbiting the Sun primarily within the Main Asteroid Belt between Mars and Jupiter. Numbering over a million, these "minor planets" range from tiny pebbles to Ceres, a nearly 1,000 km wide dwarf planet.

Location: While most inhabit the main asteroid belt, some exist in other locations, including the orbital paths of planets (Trojan asteroids).

Composition: Primarily composed of rocky and metallic materials, they are categorized into C-type (carbonaceous), S-type (siliceous), and M-type (metallic).

Structure: Unlike planets, asteroids are generally irregularly shaped, tumbling, and irregular in form.

Formation: They are considered debris from the solar system's formation, specifically materials that never successfully grew into planets.

Size: Ranging from 6 feet to hundreds of miles across, their combined mass is less than that of Earth's Moon.

Exploration: Spacecraft, such as NASA's Psyche, are currently, or have previously, studied these objects.

Distinction: Unlike comets, which are largely ice and dust and develop tails, asteroids are predominantly rock and metal and remain solid.

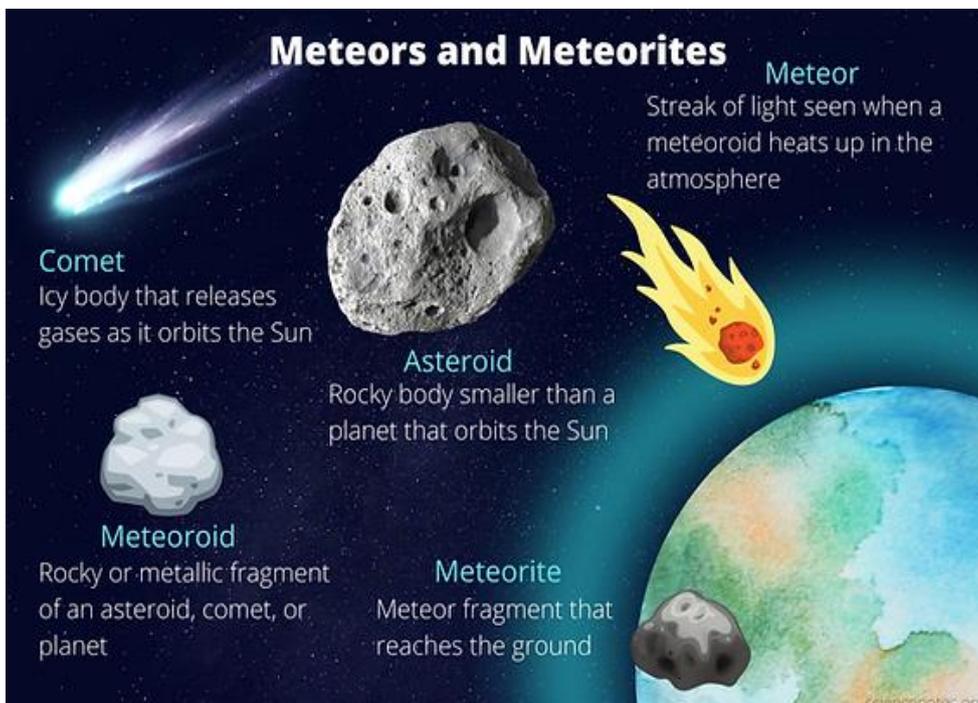


Figure 3: Asteroids, Meteoroids, Meteor and Comet.

**Impact:** Meteorites are small pieces of asteroids that have broken off and landed on Earth.

Asteroid temperatures vary significantly based on their distance from the Sun, rotation, and surface composition, generally ranging from around (-73°C, 200°K) to (-108°C, 165°K) in the main belt. Due to lack of atmosphere, surfaces can experience extreme, rapid fluctuations, with some areas on asteroids like Bennu reaching up to (76°C, 170°F).

Average Belt Temperature: Roughly (-90°C, -130°C).

**Distance Variation:** Dust particles in the main belt range from roughly (200°K, -73°C) at (165°K, -108°C).

**Surface Fluctuations:** Without an atmosphere to distribute heat, surface temperatures on asteroids like Bennu vary drastically, from to 200°K to 350°K).

**Maximum Temperatures:** Some studies suggest maximum surface temperatures on certain asteroids can reach as high as (-99.67°F to 170°C).

**Distance from the Sun:** Solar radiation is the primary heat source.

**Rotation:** Sides alternately face the sun and cold space, creating vast temperature differences.

**Albedo (Reflectivity):** Darker asteroids absorb more heat, resulting in higher temperatures.

#### **Atmospheric Entry (Meteors)**

When entering Earth's atmosphere, compression heats the air in front of a meteor to extreme temperatures, often melting the surface and raising it to over.

Friction during the 10-15 second fall can make the surface of a meteoroid glow red-hot, reaching up to 1800°C.

At the time the description 'minor planet' began to be used, the most widely disseminated values for the diameters of the first four asteroids discovered were Ceres, 2613 km; Pallas, 3380 km; Juno, 2290 km; and Vesta, "not more than 383 km".

Asteroids range from tiny, 10-meter (33-foot) rocks to massive bodies nearly 1,000 km (620 miles) across. The largest is the dwarf planet Ceres (approx. 940 km diameter), followed by Vesta and Pallas (approx. 500 km). Most are small, irregularly shaped rocky remnants found in the main belt, with millions existing. Asteroids are rocky, airless remnants from the formation of the solar system, primarily found in the belt between Mars and Jupiter. They are classified by composition into C-type (carbon-rich/dark), S-type (stony/silicate), and M-type (metallic). Ranging from tiny rubble to hundreds of kilometers wide, many are fragments from ancient collisions. Italian astronomer Giuseppe Piazzi discovered

the first asteroid, Ceres, on January 1, 1801, initially thinking it was a planet or comet. Since then, over 1.1 million asteroids have been identified, primarily located in the main belt between Mars and Jupiter. Early discoveries included Pallas, Juno, and Vesta. **Giuseppe Piazzi CR** [16 July 1746 – 22 July 1826] was an Italian Catholic priest of the Theatine order, mathematician, astronomer famous for discovering Ceres, the first known asteroid/dwarf planet, on January 1, 1801.<sup>[11-15]</sup>



**Figure 4: Giuseppe Piazzi CR.**

#### **Asteroid Size Breakdown**

**Largest (Dwarf Planets/Protoplanets):** Ceres (940 km), 4 Vesta (approx. 525 km), 2 Pallas (approx. 511 km), and 10 Hygiea (approx. 433 km).

**Intermediate:** Many asteroids are between 1 km and 100 km in diameter.

**Small/Near-Earth:** Ranges from the size of a building to tiny, 1-meter (3.3 ft) rocks.

"City Killers": Ranging from the size of a building to about two city blocks.

**Extinction Level:** The asteroid that caused the dinosaur extinction was approximately 10 km (6 miles) in diameter.

**Shape:** While the largest are nearly spherical, most are irregular.

**Population:** The number of asteroids decreases significantly with increasing size.

**Density:** They are less dense than the Moon, with many being "rubble piles" held together by gravity.

The primary difference between a meteor (ulka) and an asteroid is their location, size, and what happens when they interact with Earth's atmosphere. An asteroid is a large, rocky, or metallic body orbiting the Sun in space, while a meteor (ulka) is the streak of light produced when a small piece of a space rock (meteoroid) burns up in Earth's atmosphere.<sup>[16-20]</sup>

**Table 1: Difference between asteroid and meteor.**

Feature	Asteroid	Meteor (Ulka/Shooting Star) Asteroid
Location	In space (mostly between Mars and Jupiter)	In Earth's atmosphere
Size	Large (up to hundreds of miles across)	Tiny (usually dust to pebble-sized)
Visibility	Viewed through telescopes	Visible as a streak of light (fireball)
Nature	Rocky/Metallic remnants of solar system formation	A burning meteoroid

**Detailed Breakdown**

- **Asteroids (Space Rocks):** These are leftovers from the formation of our solar system, essentially "minor planets". They mostly reside in the asteroid belt between Mars and Jupiter. They are rocky or metallic, irregular in shape, and do not have a tail.
- **Meteors (Ulka/Shooting Star):** When an asteroid or comet breaks apart, it creates smaller chunks called meteoroids. When a meteoroid enters Earth's atmosphere at high speed, friction causes it to burn up, producing a streak of light known as a meteor or "shooting star".
- **Meteorite (Ulka Pinda):** If the rock is large enough to survive the passage through the atmosphere and hits the ground, it is called a meteorite.

**SUMMARY OF TERMINOLOGY**

**Asteroid:** In space.

**Meteor (Ulka):** Burning in the atmosphere.

**Meteorite (Ulka Pinda):** Landed on the ground.

In simple terms, the difference between asteroids and meteoroids depends on the question of location. Asteroids are found in space. When it enters an atmosphere, it is known as a meteor, and when it hits the ground, it is known as a meteoroid. Basically, both are made of rocks and minerals. An asteroid is a small rocky object, usually irregularly shaped, that orbits the Sun. Comets are similar to asteroids, but icier because they formed farther from the Sun and continue to spend most of their time there.<sup>[20-25]</sup>

**Meteoroids**

These are small, rocky, or metallic debris (dust to small asteroid size) floating in space. When they enter Earth's atmosphere, friction burns them up, creating a streak of light called a meteor. If any part of that object survives the atmosphere and lands on Earth, it is called a meteorite. A meteoroid is a small rocky or metallic body traveling through outer space, ranging in size from dust grains to small, boulder-sized objects up to one meter wide. They are generally debris from asteroids or comets. When a meteoroid enters Earth's atmosphere, it becomes a meteor (a light streak), and if it hits the ground, it is called a meteorite.

**CONCLUSION**

An asteroid is a small, rocky, airless remnant from the early solar system, orbiting the Sun, similar to a planet but much smaller, ranging from pebble-sized to hundreds of kilometers wide. They are essentially leftover building blocks from planet formation, composed of rock, metals (like nickel and iron), or clay, and are typically found in the asteroid belt between Mars and Jupiter, though some

have orbits that cross Earth's path. They have irregular shapes, craters, and lack the atmosphere or tail of a comet.

**Composition**

Mostly rock and metal (iron, nickel), but can also contain clays, silicates, and organic compounds.

**Size & Shape:** Varies greatly, from tiny boulders to Ceres (a dwarf planet) nearly 1,000 km across; generally irregular and cratered.

**Location:** Primarily in the Main Asteroid Belt (between Mars & Jupiter) but also in other orbits, including Earth's vicinity.

**Origin:** Leftover material from when the solar system formed about 4.6 billion years ago.

**Classification:** Broadly C-type (carbonaceous, dark), S-type (stony, bright), and M-type (metallic, bright).

Asteroids vs.

**Comets & Meteors**

**Comets:** Icy bodies that develop a temporary atmosphere (coma) and tail when near the Sun, unlike asteroids.

**Meteoroids:** Small fragments of asteroids or comets.

**Meteors:** Meteoroids burning up in Earth's atmosphere (shooting stars).

**Meteorites:** Meteoroids that survive passage through the atmosphere and land on Earth.

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