Meteorite Training Kit Vocabulary List

The following Vocabulary List and meteorite subclasses have been put together from a variety of sources. This is for your information only and is not to be distributed to the public since we have taken material freely from these sources and may not have included proper references in all cases.

Accretion (Planet or Asteroid)

The formation of the major observational features of our Solar System can all be explained through a scenario of gradual growth through collisions. In this scenario, the Solar System started as a cloud of gas and dust that slowly collapsed into a flattening disk. Initially, dust grains grew into larger and larger clumps through simple collisions, but over time objects grew large enough that they also began to grow by gravitationally attracting nearby material. This type of an accretion tended to form bodies rotating in the same prograde direction that the disk rotates. Dynamical studies also suggest typical rotation periods in our Solar System should be 5 to 20 hours, which is consistent with our observations of planets and asteroids. [from http://m.teachastronomy.com/astropedia/article/Accretion-and-Solar-System-Bodies; C.Impey, University of Arizona].

Achondrite

Achondrites look like Earth rocks. As indicated by the name, they lack chondrules. They were once completely molten and thus contain no water or other volatiles. Achondrites come from a differentiated parent body (asteroid, planet, or the Moon). Some achondrites are called regolith *breccias*,

- *Eucrites* are basalt-like achondrites that originated from extrusive volcanic rocks on the surface of a differentiated asteroid. *Diogenites* are "mantle-like" meteorites composed mostly of olivine and pyroxene, minerals common in the mantle of the Earth. *Howardites* are meteorites (regolith breccias) that are a mixture of eucritic and diogenitic material and sometimes contain carbonaceous chondritic material. These meteorites are thought to come from the asteroid Vesta, though some HEDs may have derived from at least one other parent body. Collectively, they are called HEDs.
- Other achondrite meteorites have been shown to have come from the Moon and Mars.
- There is also a class of meteorites called primitive achondrites. This includes both stony meteorites as well as some iron meteorites. "They are classified on the same rank (historically called "Class") and lying between chondrites and achondrites. They are called primitive because they are achondrites that have retained much of their original chondritic properties. Very characteristic are relic chondrules and chemical compositions close to the composition of chondrites. These observations are explained as melt residues, partial melting, or extensive recrystallization." From Wikipedia

Asteroid

Asteroids are minor planets, especially those of the inner Solar System. The larger ones have also been called planetoids. These terms have historically been applied to any astronomical object orbiting the Sun that did not show the disk of a planet and was not observed to have the characteristics of an active comet, but as minor planets in the outer Solar System were discovered, their volatile-based surfaces were found to more closely resemble comets and so were often distinguished from traditional asteroids. Thus the term *asteroid* has come increasingly to refer specifically to the small bodies of the inner Solar System out to the orbit of Jupiter. They are grouped with the outer bodies–centaurs, Neptune trojans, and trans-Neptunian objects—as minor planets, which is the term preferred in astronomical circles. As of early December 2013, the Minor Planet Center had data on more than one million objects, of which nearly 628,000 had enough information to be given numbered designations. [from http://en.wikipedia.org/wiki/Asteroid].In 2006, when the International Astronomical Union redefined Pluto and several other objects as Dwarf Planets, they also defined a new term—Small Solar System Body—which is defined as any object in the Solar System that is not a planet, Dwarf Planet, or satellite, so includes comets. When an asteroid is discovered, and re-observed over several days, it will be given a provisional designation that is the year followed by a series of letters and numbers. Once an asteroid had been observed for a long-enough period so that it is unlikely that it will ever be "lost," then it is given a number designation and the discoverer can name it.

Asteroid Belt

The asteroid belt is the region of the Solar System located roughly between the orbits of the planets Mars and Jupiter. It is occupied by numerous irregularly shaped bodies called asteroids or minor planets. The asteroid belt is distinct from asteroids in the Solar System such as near-Earth asteroids and trojan asteroids. About half the mass of the belt is contained in the four largest asteroids, Ceres, Vesta, Pallas, and Hygiea. Ceres, the asteroid belt's only dwarf planet, is about 950 km in diameter. The remaining bodies range down to the size of a dust particle. The asteroid material is so thinly distributed that numerous unmanned spacecraft have traversed it without incident. Nonetheless, collisions between large asteroids do occur, and these can form an asteroid family whose members have similar orbital characteristics and compositions. The asteroid belt formed from the primordial solar nebula as a group of planetesimals, the smaller precursors of the planets, which in turn formed protoplanets. Between Mars and Jupiter, however, gravitational perturbations from Jupiter prevented the protoplanets from accreting into a planet. Collisions became too violent, and instead of fusing together, the planetesimals and most of the protoplanets shattered. As a result, 99.9% of the asteroid belt's original mass was lost in the first 100 million years of the Solar System's history. Asteroid orbits continue to be appreciably perturbed whenever their period of revolution about the Sun forms an orbital resonance with Jupiter. At these orbital distances, a gap occurs as they are swept into other orbits. http://en.wikipedia.org/wiki/Asteroid_belt

Breccia

Regolith breccias are rocks composed of broken fragments of minerals or rock cemented together by a fine-grained matrix. The rock formed from impact ejecta which was later buried by newer impacts and lithified (solidified) due to the pressure from overlying layers. Regolith breccias are not found on Earth due to a lack of regolith on bodies which have an atmosphere.

Chondrite

Chondrites are primitive (undifferentiated) meteorites. Chondrites are stony (non-metallic) meteorites that are made up mostly of silicates, traces of iron, and sometimes carbon and water. Chondrites have not been modified due to melting or differentiation of the of the parent body. About 85% of all meteorite fall are chondrites. Many, but not all, chondrites contain chondrules. Ones that do not have been chondrules have been altered by water or mild heating. The three most common chondrites are described below. http://en.wikipedia.org/wiki/Chondrite

- *Carbonaceous Chondrites* are very dark brown or black in color. Chondrules are usually abundant, but some meteorites also contain small, white amoeba-like inclusions called CAIs (calcium-aluminum inclusions) that are the oldest materials known in the Solar System. Carbonaceous chondrites contain water and carbon compounds along with all the other elements (except hydrogen and helium) in the same relative abundances as we find in the Sun. They are essentially clods of "solar dust." There are four subclasses of carbonaceous chondrites (CI, CM, CO, CV) divided according to the amount of water and carbon. CIs and CMs have been aqueously altered and so may not show signs of chondrules.
- *Ordinary Chondrites* are gray to brown or dark brown in color. They usually look like typical grainy Earth rocks except for: 1) chondrules and 2) the almost universal presence of tiny grains of metal (mostly iron-nickel) that can easily be seen in reflected light. The metal grains are recognizable even when the chondrules are "faded" and hard to see due to heating. Ordinary chondrites are similar to carbonaceous chondrites in composition except they lack water, carbon, and some elements with very low melting points. Ordinary chondrites are classified as H (High in iron; very common), L (Low in iron; uncommon), and LL (very low in iron; very uncommon). All H chondrites apparently come from a single parent body.
- *Enstatite Chondrites* are very rare chondrites so named because they contain large quantities of the mineral enstatite. Only about 2% of all chondrites are enstatite chondrites.

Chondrule

Chondrules are round grains found in chondrites. Chondrules form as molten or partially molten droplets in space before being accreted to their parent asteroids. Chondrites represent one of the oldest solid materials within our Solar System and are believed to be the building blocks of the planetary system. There are a number of mechanisms that have been proposed for the formation of chondrules: impacts between molten planetesimals, meteor ablation, hot inner nebula, flare-up of the early Sun, energetic bipolar-shaped outflows from the Sun, nebular lightning, magnetic flares, shock waves in the protoplanetary disk supernova radiation and shock wave, and volcanic eruptions.

Comet

A comet is an object that orbits the Sun. Comets are mostly icy and so, when close to the Sun, they display a visible coma and sometimes a tail. Comets range in size from a few tens of meters to tens of kilometers across. Asteroids and comets are classified based on their physical appearance as viewed through Earth-based telescopes, not on their physical properties! Definition—star-like, asteroid, vs. fuzz**y,** comet**.**

Physical Structure

The tail can be >1 AU long and always points away from the Sun. There are normally two tails, an ion tail that is straight and a dust tail that is curved due to the effects of the solar wind. The tenuous coma can be as big as the Sun and contains both gas and dust. The tail is typically 1–20 km in diameter and is a mixture of ices and dust as well as "organic" material (hydrocarbons). Generally, until the comet comes within 4 AU, we do not see coma and tail when water ice sublimates (turns from solid ice to gas).

Dynamical Properties

Comet orbital inclination almost random (implying that their source is sphere, not a disk). Many have retrograde orbits. The ones we see in very elliptical orbits (aphelion 50,000 AU), typically have million-year orbits. Short-period comets appear to be derived from long period, captured by Jupiter. All (known) comet are bound to the Solar System. The sources of the comets are the Kuiper belt and the Oort cloud. We have observed objects in the Kuiper belt, but, because of its great distance, we have never observed an Oort cloud object.

Differentiation (Planet or Asteroid)

Planetary differentiation is the process of separating out different constituents of a planetary body as a consequence of their physical or chemical behavior, where the body develops into compositionally distinct layers; the denser materials of a planet, moon, or asteroid sink to the center, while less dense materials rise to the surface. Such a process tends to create a core and mantle. Sometimes a chemically distinct crust forms on top of the mantle. The process of planetary differentiation has occurred on planets, dwarf planets, the asteroid 4 Vesta (and probably other large asteroids), and natural satellites (such as the Moon).
http://en.wikipedia.org/wiki/Planetary_differentiation

Differentiated Meteorite

Differentiated meteorites come from differentiated parent bodies (asteroids, the Moon, and Mars). These include *achondrites* (stones), *pallasites* and *mesosiderites* (stony-irons), and *irons.*

Fall (Meteorite)

When a fireball is observed and meteorites are recovered, this is called a meteorite fall. Falls are quite rare. As of mid-2013, there were just over 1,100 officially witnessed falls.

Find (Meteorite)

A find refers to a meteorite that has been found and has no record of having been witnessed falling to the Earth's surface. As of mid-2013, there were about 45,000 documented finds.

Fireball

A fireball is a brighter-than-usual *meteor*. It is usually defined as a meteor brighter than the planet Venus at its brightest, magnitude −5. However, the International Meteor Organization uses magnitude −3.

Iron Meteorite

Iron meteorites are differentiated meteorites and are thought to represent the cores of differentiated asteroids. Iron meteorites consist of almost pure metallic iron with small amounts of nickel and sulfur. Polished faces are commonly treated with dilute nitric acid to bring out the Widmanstätten pattern—parallel patterns of lines intersecting at various angles delineating bands of crystals of kamacite (low nickel) and taenite (high nickel) iron alloys. Iron meteorites were once completely molten and, as indicated by sizes of some individual crystals as large as several meters, cooled slowly over millions of years. It is estimated that the parent bodies of the iron meteorites ranged from a little over 100 km to nearly 1,000 km (the size of Ceres) in diameter. Irons are grouped by chemical composition. Known irons originate from 60−70 parent bodies.

Composition

Iron and nickel form an alloy (a solid solution). Sometimes iron meteorites contain carbon nodules.

- *Kamacite* is an alloy of iron and nickel that can range from 5% to 10% nickel in iron meteorites.

- *Taenite* is an alloy of iron and nickel that can range from 20% to 65% in iron meteorites.

Classification

Irons meteorites are classified by their visual appearance which is indicative of their composition. [*Meteorites*, by Alain Carion]

- *Octahedrites* contain 7% to 15% nickel and are therefore composed of both kamacite and taenite, showing the Widmanstätten pattern.
- *Atazites* have no visible structure. This is because of their high nickel content which can exceed 60%
- *Hexahedrites* contain 5% to 6% nickel and hence are almost pure kamacite. Nitric acid does bring out a pattern of parallel lines, the Neumann lines. These were formed by pressure and stress on the kamacite.

Lunar Meteorites

Lunar meteorites are, as the name implies, meteorites derived from impacts on the Moon. Lunar meteorites are differentiated achondritic meteorites. There are two major classes of lunar meteorites (and *lunar rocks*): mare basalts (derived from the mare) and lunar breccias (derived from the lunar highlands). The term KREEP is used for one of the components of lunar rocks and meteorites (primarily *lunar rocks*). The term KREEP comes from the geochemical components of the rocks: K (the atomic symbol for potassium), REE (Rare Earth Elements), and P (phosphorus). KREEP-containing rocks are primarily concentrated underneath Oceanus Procellarum and Mare Imbrium. This is a unique lunar geological province that is now known as the Procellarum KREEP Terrane (PKT). http://meteorites.wustl.edu/lunar/moon_meteorites.htm, http://en.wikipedia.org/wiki/KREEP

Lunar Rocks

Lunar rocks is a term used to describe rocks brought back from the Moon as opposed to lunar meteorites. The six Apollo missions brought back about 382 kg (842 lb) of rocks. The Soviet Union's three Luna spacecraft returned 0.32 kg (0.7 lb) of lunar rocks. This can be compared to the approximately 48 kg (105 lb) of lunar meteorites that have been found on the Earth. http://en.wikipedia.org/wiki/Moon_rock

Martian Meteorites

Martian meteorites are, as the name implies meteorites from the planet Mars. All martian meteorites are differentiated achondritic meteorites. There are three classes of martian meteorites that are collectively called SNCs.

Shergottites

About three-quarters of all martian meteorites can be classified as shergottites. They are named after the Shergotty meteorite, which fell at Sherghati, India in 1865. Shergottites are igneous rocks. The shergottites appear to have 5rystallized as recently as 180 million years ago, which is a surprisingly young age considering how ancient the majority of the surface of Mars appears to be, and the small size of Mars itself. Because of this, some have advocated the idea that the shergottites are much older than this. This "Shergottite Age Paradox" remains unsolved and is still an area of active research and debate.

Nakhlites

Nakhlites are named after the first of them, the Nakhla meteorite, which fell in Alexandria, Egypt in 1911.Nakhlites are igneous rocks that were formed from basaltic magma about 1.3 billion years ago. They contain augite and olivine crystals. Their crystallization ages, compared to a crater count chronology of different regions on Mars, suggest the nakhlites formed on the large volcanic construct of either Tharsis, Elysium, or Syrtis Major Planum. It has been shown that the nakhlites were suffused with liquid water around 620 million years ago and that they were ejected from Mars around 10.75 million years ago by an asteroid impact. They fell to Earth within the last 10,000 years.

Chassignites

Chassigny is a Mars meteorite which fell on October 3, 1815 in Chassigny, Haute-Marne, France. Chassigny is the meteorite for which the chassignites are named.. Chassigny is an olivine cumulate rock (dunite). It consists almost entirely of olivine with pyroxene, feldspar, and oxides. Chassigny was the only known chassignite until NWA2737 was found in the Moroccan Sahara in northwest Africa. Chassigny is particularly important because, unlike most SNCs, it contains noble gas compositions different from the current martian atmosphere. These differences are presumably due to its cumulate (mantle-derived) nature. http://en.wikipedia.org/wiki/Martian_meteorite

Metamorphism

Metamorphism is the change of minerals or geologic texture (distinct arrangement of minerals) in pre-existing rocks, without the rock melting into liquid magma (a solid-state change). The change occurs primarily due to heat, pressure, and the introduction of chemically active fluids. The chemical components and crystal structures of the minerals making up the rock may change even though the rock remains a solid. Metamorphism typically occurs between about 200°C and melting at about 850°C. Three types of metamorphism exist: contact, dynamic and regional. http://en.wikipedia.org/wiki/Metamorphism

Meteor

A meteor or "shooting star" is the visible streak of light from a *meteoroid* or micrometeoroid, heated and glowing from entering the Earth's atmosphere, as it sheds glowing material in its wake. Meteors typically occur in the mesosphere at altitudes between 76 km to 100 km (46–62 miles). The root word *meteor* comes from the Greek *meteōros*, meaning "suspended in the air." What we actually see is the glow of the heated air (heated by the bow shock of the meteoroid traveling much faster than the speed of sound) as well as the material coming off of the meteoroid. http://en.wikipedia.org/wiki/Meteoroid

Meteoroid

A meteoroid is an object that orbits the Sun, but is smaller than an asteroid. They range in size from a speck of dust to a few meters across.

Primitive Meteorite

A primitive meteorite refers to a meteorite that has a composition similar to that of the Sun, minus the "volatile" elements (hydrogen, helium, for example). These are thought to come from undifferentiated asteroids, some of which may have been mildly heated. These meteorites include the *chondrites* as well as the primitive achondrites. These achondrites are called primitive because they are achondrites that have retained much of their original chondritic properties. Very characteristic are relic chondrules and chemical compositions close to the composition of chondrites.

These observations are explained as melt residues, partial melting, or extensive recrystallization. http://www.meteoris.de/basics/class2.html, http://en.wikipedia.org/wiki/Primitive_achondrite, Dr. Alan Rubin: "Secrets of Primitive Meteorites," in *Scientific American* February 2013.

Stone (Meteorite)

Stone meteorites represent about 97% of all of the meteorites either found or seen to fall. This group of meteorites includes *chondrites* and *achondrites*. See http://meteorites.wustl.edu/meteorite_types.htm for statistics on all meteorites.

Stony-Iron (Meteorite)

Stony-iron meteorites are meteorites that consist of nearly equal parts of meteoric iron and silicates. This distinguishes them from the stony meteorites, that are mostly silicates, and the iron meteorites, that are mostly meteoric iron. They are all differentiated meteorites. The stony-irons are divided into mesosiderites and pallasites..

- *Pallasites* exhibit droplets of olivine (peridot) imbedded in pure iron-nickel. In polished sections, the olivine appears as translucent crystals. Upon etching the iron portions of pallasites often exhibit the *Widmanstätten Pattern.* Until recently, pallasites were once thought to represent the core-mantle boundary of differentiated asteroids that were subsequently shattered through impacts. A more recent theory proposes that they are impact-generated mixtures of core and mantle materials.
- *Mesosiderites* contain large amounts of metal "splashed" throughout the rocky component of the meteorite. Mesosiderites often look like ordinary chondrites, except the metal occurs in long stringers and "splashes" of iron, and not just in flecks. Mesosiderites are thought to originate in impacts of stone and iron objects at velocities sufficient to melt the iron.

Tektite

Tektites are made of black or green opaque to translucent glass; with pitted or grooved surfaces and shaped like ovoids, teardrops, or "buttons." Sometimes they contain small bits of imbedded silicate soil or rock. Most of the world's tektites are found in four large "strewnfields:" 1) the Australasian field (including Indochinites and Australites), thought to have been derived from the El Gygytgyn crater in eastern Siberia, 2) the North American field derived from the Chesapeake Bay Crater, 3) the green Moldavite tektites found principally in the Czech Republic, from the Ries Crater in Germany, and 4) the Ivory Coast field, from the Bosumtwi Crater in Ghana.

Widmanstätten Pattern

See discussion under *Iron Meteorites.*