In ancient times, the notion of small particles or atoms making up matter was conceived by philosophers first in Hindu India and then in the Mediterranean (Greek) region. Kanada developed an atomic theory in India where five elements were known, air, water, fire, earth, and space. In the Mediterranean (Greek) region, Democritus and Leucippus are considered to be the founders of the atomism in the fifth century BCE. Aristotle did not accept the atomic theory but did accept the four elements, air, water, earth, and fire. Among the Arab alchemists, there was little interest except for followers of Kalâm who developed an atomic theory. In Europe, the Aristotelian view dominated until the sixteenth century CE. The four elements of Empedocles (earth, air, water, fire) or the three principles of Paracelsus (mercury, sulfur, salt) were not included in Lavoisier’s Table of Simple Substances in 1789 CE. In the eighteenth century, there was the revival of the ancient Greek atomism in the guise of corpuscularism preceding the atomism of John Dalton.

The notion of atoms arrived in the East, ancient India, prior to its appearance in the West, the ancient Mediterranean (Greek) world. Both societies were polytheistic, and philosopher-chemists dominated the study of chemistry. Atomic concepts were based upon philosophical considerations and not experimental observations. No exchange on atomism between these two regions in this ancient time has been detected, indicating that these concepts were developed independently (7). These developments occurred during Period I of the Ancient Regime of Chemistry (~10,000 BCE - ~100 BCE), which may be called the
era of Philosophical Chemistry because the philosophers of the time were the theoretical chemists. Of course, there were other forms of chemistry that were practiced. For example, the first recorded industrial chemists were two women, Tapputi-Belatekallim, the Perfumeress and ...Ninu, the Perfumeress, in Babylonia in about 2000 BCE. The full name of ...Ninu is not known due to lacunae in a cuneiform tablet, which was written in Akkadian, the language of Mesopotamia during the reign of Tukulti-Ninurti I (1256-1209 BCE) (2).

Indian Atomism

The atomic concept developed differently in the various religions prevalent in ancient India. These views survived until after the British conquest in the 18th century when the educational system was revamped to emulate the British educational system.

Hinduism

In the Bhagavad Gītā, one of the holy books of Hindus, which was written between 300 and 500 BCE (3), a reference to atoms appears in verse 9, chapter 8. It is written in Sanskrit: kavim purāṇam anusāsitāram aŋor anīyāṁsam anusmared yah sarvasya dhātāram acintya-rūpam āditya-varnam tamasah parastāt, where aŋor refers to atom. One translation is (4): He who meditates on the one who is all-perceiving, the ancient, the ruler of all things, smaller than the atom, the supporter of this universe, whose form is inconceivable, who is as radiant as the sun beyond the darkness. Swami Prabhupada (5) offers a different translation: “One should meditate upon the Supreme Person as the one who knows everything, as He who is the oldest, who is the controller, who is smaller than the smallest, who is the maintainer of everything, who is beyond all material conception, who is inconceivable, and who is always a person. He is luminous like the sun and, being transcendental, is beyond this material nature.” In his commentary on this verse (5), he states “He is called the smaller than the smallest. As the Supreme, He can enter into the atom.”

Kanada, a Nyaya-Vaisheshika philosopher, who lived ~600 BCE, considered that matter was composed of four types of atoms, earth, fire, air, and water. Atoms reacted with the aid of an invisible force (adrsta) to form biatomic molecules and triatomic molecules (6–8). He stated that there were five elements: earth, fire, air, water, and space. Each atom also had qualities such as odor, taste, color and a sense of touch (8).

Jainism

In Jaina atomism (~900 BCE), the atom was the indivisible particle of matter. Each atom had attributes such as color, taste, and odor, as well as tactile qualities such as roughness or moistness. Atoms existed in space. The combination of atoms was produced by the differences in attributes such as roughness (8).
**Buddhism**

In the Sarvastivadin school of Buddhism (~400 BCE), the minimum indivisible particle of matter was called the atom, which expresses the nature of matter. The characteristic atoms were earth (solid), water (liquid), fire (heat), air (moving), color, taste, odor, and sense of touch, and they existed in space. The smallest composite unit was considered to be composed of seven characteristic atoms, which are set at the apices and center of octahedron (8).

**Chinese Atomism**

Based upon Taoist philosophy, alchemy in China developed. Although there is not any literature concerning atomism among the ancient Chinese alchemists, five elements (Wu Xing) were acknowledged in the twelfth century BCE. These elements were water, fire, wood, gold or metal, and earth. The elements were frequently associated or matched with other sets of five, such as virtues, tastes, colors, tones, and the like (9). In about 1910, modern atomism probably came to China when Sun Yat Sen introduced modern European education.

**Mediterranean (Greek) Atomism**

On the other side of the Ancient world, thinking about atoms was initiated by Sanchuniathon of Sidon in Phoenicia around 1200 BCE (10). As first principles, he considered air and ether. Poseidonios (135-51 BCE) stated that Sanchuniathon “originated the ancient opinion about atoms” according to Strabo, a geographer and writer in the ancient world (10). Robert Boyle in the seventh century, CE, noted that Mochus or Moschus of Sidon was the first to devise an “atomical hypothesis” (11). This Moschus should not be confused with the poet of the same name of Syracuse (12) nor the philosopher of the same name of Elis (13), both of whom lived at a later period.

**Four Elements**

North of Phoenicia on the west coast of Asia Minor in the city of Miletus, Thales (630-550 BCE), the first Greek philosopher, taught that the primary substance was water on which the earth floats, and all things contain gods (14). His pupil, Anaximander or Aleximandros (611-545 BCE) replaced water with apeiron (15). The primary substance according to Anaximenes (585-525 BCE), who succeeded Anaximander, was air or breath. By condensation, it became wind, cloud, water, earth, and stone and by rarefaction, fire (16). Fire was the choice of Heraclitus (540-450 BCE) of Ephesus (Asia Minor) as the primary substance (17). Xenophanes (550-450 BCE) of nearby Colophon suggested that earth was the primary substance (18).

On the island of Sicily in the city of Akragos (Agrigentum), Empedocles (483-430 BCE) proposed a theory of four primordial substance or roots. He associated them with deities, the identity of which varied with the source; Zeus (air or fire), Hera (air or earth), Aidoneus (air, earth, or fire), and Nestis (water) (19). Each root
consisted of particles that were indivisible, homogeneous, changeless, and eternal with pores (not void) between the particles. The particles move with Love as the physical agent for mixing of the particles and for their separation, Strife (19). Until the end of the eighteenth century, CE, this theory of four elements (seeds) persisted with the addition of mercury, sulphur, and salt.

First Defined Atomism

In contrast to Eleatic School (Parmenides and Empedocles), Leucippus of Miletus (~500-? BCE) and his pupil, Democritus of Abdera (460-370 BCE) introduced the void as being necessary for the motion of corpuscles or atoms. Atoms are indivisible, solid, full, and compact with various shapes. They also were in motion and have weight (20).

Born in Athens, using Pythagorarian concepts, Plato (427-347 BCE), a pupil of Socrates, conceived geometric bodies for the units or particles of the seeds, which he called elements. Earth units were cubes, fire units, tetrahedrons, air units, octahedrons, and water units, icosahedrons (21). He did not accept the void but thought that space existed inside the units. The units of fire, air, and water were deformable corpuscles. In his dialogue, Timaeus, he wrote “God placed water and air in the mean between fire and earth, and made them to have the same proportion so far as was possible (as fire is to air so is air to water, and as air is to water so is water to earth); and thus he bound and put together a visible and tangible heaven. And for these reasons, and out of such elements, which are in number four, the body of the world was created” (22).

Aristotle of Stageiros (384-322 BCE) did not agree with his teacher’s geometric bodies for the different elements. He rejected the Democritian atoms in which matter was considered a principle but form was a secondary characteristic. Nor did he accept the existence of a void. According to the Aristotelian view, the four elements arose from the action on primordial matter by pairs of qualities (warm + dry, fire, warm + moist, air, cold + dry, earth, cold + moist, water). He introduced another element, ether, as a divine substance of which the heavens and stars are made (23).

Lucretius (Titus Lucretius Carus, ~99 BCE - ~55 CE) of Rome wrote a poem, De Rerum Natura (On the Nature of Things) (24) in which he described the atomic theory of Epicurus of Samos (342-271 BCE). For Epicurus, atoms were indivisible, invisible, and indestructible, and they differ in size, shape and weight. He believed that a void exists because there can be no motion of the atoms without it. The motions of atoms included the downward motion of free atoms because of their weight, “swerve,” the deviation of atomic motion from straight downward paths, and “blow,” which results from collisions and motion in compound bodies. Lucretius called atoms poppy seeds, bodies, principals, and shapes (25).

Galen of Pergamum (129-216 CE) rejected the atomic theory because the grouping of atoms could not explain why the properties of a compound differed from the properties of its constituents (26). His rejection effectively exiled atomism in the Western world in which the views of Aristotle prevailed until the seventeenth century, CE (27).

Alchemy

The second period of the Ancient Regime of Chemistry, alchemy, alchimi, alchimi or chymistry, began ~100 BCE and continued until the end of the eighteenth century, CE. In Egypt, the priests engaged in secret alchemical operations. As a result of this association of alchemy with the priests, alchemy became identified with magic. After Rome conquered Egypt and Emperor Constantine converted to Christianity, the administration of the empire was dominated by Christians intolerant of those who did not agree with the official views. Many of the alchemists were Gnostics exiled from the Roman Empire in the fifth century, CE. Also expelled were the Nestorians who carried the writings of the Greek philosophers, which were translated into Syrian in Persia. After Mohammad’s death in 632 CE, his followers from Arabia created an empire from Persia to Spain. In Persia, the Greek texts including alchemical tracts were translated into Arabic (29).

Arabian Atomism

There was little interest in atomism except for the followers of the philosophy of Kalam (Arabic: speech). Among the main proponents were the Mutazilites (from i’tazala, to separate oneself, to dissent). Of the twelve propositions of Kalam, the first nine were directly related to atoms. These propositions include:

- “All things are composed of atoms that are indivisible, and when atoms combine, they form bodies.”
- “There is a vacuum.”
- “Time is composed of time-atoms”
- “Substances cannot exist without accidents”. Accidents are properties such as color, taste, motion or rest, and combination or separation.
- “Atoms are furnished with accidents and cannot exist without them”
- “Accidents do not continue in existence during two time-atoms. God creates substances and the accidents” (30).

Medieval European Alchemy

In the twelfth and thirteenth centuries in Europe, Greek and Arab texts were translated from Arabic into Latin, the literary language of Europe. The first translation of an alchemical book from Arabic, *The Book of the Composition of Alchemy*, was prepared by Robert of Chester in 1144 CE in Spain (31). To the Four Elements, air, water, fire, and earth, Arab alchemists added mercury and sulfur. Paracelsus considered mercury and sulfur as principles along with salt...
Aristotelian atomism was the only view accepted by the alchemists and the authorities (Catholic Church). Few if any references to atoms were made by alchemists in their writings. For example, in *The Ordinall of Alchemy* (1477) by Thomas Norton of Bristoll, atoms are mentioned once in the 123 pages:

> Substance resolving in Attomes with wonder

**Sympathizers and Atomists of the Twelfth to the Fourteenth Centuries, CE**

The sympathizers, Adelard of Bath (died ~1150 CE) and Thierry of Chartres (died ~1155 CE), accepted the four elements of the Greeks and that atoms or corpuscles were involved with them. Atoms were fundamental constituents of substances according to Constantine the African of Carthage (twelfth century, CE). William of Conches (1080-1154 CE) recognized God’s action as giving rise to the laws of nature and regarded atoms as “first principles” and “simple and extremely small particles” (34). Critizing Aristotelian physics, William of Ockham (1399-1350 CE) stated that substance had matter and form; its qualities result from elementary particles that can be construed to be atoms. In 1340 CE, his views were condemned by the Church as was those of Nicholas of Autrecourt (1300-1350 CE) in 1347 CE. Nicholas considered matter to be eternal, consisting of invisible atoms that are in motion; generation and corruption of substances occurs by the rearrangement of atoms (34).

In the early fifteenth century (1417 CE), *De Rerum Natura* by Lucretius was rediscovered. It was printed fifty-six years later in 1473 CE reintroducing the Epicurian concept of the atom and void to the western world (35).

**Atomists of the Sixteenth to the Eighteenth Centuries, CE**

One of the first atomists in the sixteenth century was Jean Bodin (1530-1596 CE) who considered atoms to be indivisible bodies with motion and that an infinite force was necessary for the division of atoms (36).

Giordano Bruno (1548-1600 CE) was a member of the Dominican order. His views on atoms had both metaphysical and physical aspects: atoms are both the ultimate, indeterminate, substance of things and a hypothesis that can be used to explain variety in the material world (even though only earth, among the four elements, has atoms). Each kind of being had a “minimum” or unit, although only God is a true monad: the point was the minimum of space, the atom the minimum of matter. Bruno’s atoms are spherical, and their motions due to a soul in each. He was burnt alive for heresy on February 17, 1600, in Rome (37).

A professor of medicine at Wittenberg, Daniel Sennert (1572-1637 CE) developed a version of atomism from experimental observations rather than philosophical considerations. Based upon sublimation, solution, and petrifaction, for example, the mixtures of gold-silver alloy and silver dissolved in acid, he concluded that there were corpuscles or “minima” that were divisible, and the four elements had them (36, 38).

The atomism of Sebastian Basso (17th century, CE), a French physician, was based upon Democritus atomism with no void. He considered all bodies created.
by God to consist of exceedingly small atoms of different natures with the spaces between particles filled with a subtle spirit. The element fire consisted of fine and sharp corpuscles (37, 39).

Not an ardent supporter of Democritian atomism, Sir Francis Bacon, first Viscount St. Alban, (1561-1626 CE) was also a lawyer and member of the English government. He considered atoms to be true or useful for demonstration but he did not accept the void. The properties of bodies were explained by the size and shape of corpuscles and not the indivisible atoms. Force or motion was implanted by God in the first particles (40).

Isaac Beeckman (1588-1637 CE), a Dutch natural philosopher, proposed a “molecular” theory in his “scientific diary”. He assumed that there were four kinds of atoms corresponding to the four elements of the one sole primordial matter. He considered these atoms to be the cause of the properties of the substances, for example, color, taste, smell, etc. The molecules of substances were called homogenea physica (physical homogenea) and were composed of the atoms in specific spatial structure. His private diary was available to several savants such as Descartes, who acknowledged these ideas in several books (41).

Another atomist, prosecuted by the Italian church authorities, was Galileo Galilei (1564-1642 CE). He initially used minimi to describe the smallest parts of substances but later applied the term to Epicurean atoms separated by a quantitatively infinite vacuum. The atomic structure of substances was necessary from mathematical reasoning, and the atom was indivisible without shape and dimensions. The qualities or properties (color, odor, taste, etc.) of atoms were not associated with atoms but with their sensory detection by the observer (42).

Two French contemporary students of the atomic theory were Pierre Gassendi (1592-1655 CE) and Rene Descartes (1596-1650 CE). Gassendi, a priest, was an atomist for whom atoms were primordial, impenetrable, simple, unchangeable, and indestructible bodies with shape, size, and weight that were set in motion by God at creation. In addition, he accepted that a vacuum exists, which Torricelli demonstrated in 1643 (43). In contrast, Descartes did not believe in the void, but that the material universe consisted of one infinite and continuous extended matter created by God. Extended matter consisted of a granulated continuum made of corpuscles. This corpuscular philosophy involved corpuscles that were deformable and divisible, having shapes, sizes, and motion (44). The association of God with atoms (or at least corpuscles) by Descartes and Gassendi was very instrumental in the return of Epicurean atomism as the basis of the atomic theory, and in 1678, Cudworth could include atomism in his book, The True Intellectual System of the Universe (28). Atomism had returned.

Nicholas Lemery (1645-1715 CE) was a corpuscularian who favored a five-element theory (water, spirit, oil, salt, and earth). His acid/alkali theory invoked spikes on an acid that interacted with the pores of the base. In 1675 CE in Paris, he published Cours de Chymie, a textbook that was translated into English, German, Italian, Latin, and Spanish and was popular for more than fifty years. In this book, he espoused the Cartesian corpuscular mechanism (45).

The corpuscularism of the Honorable Robert Boyle (1627-1691 CE) was based upon the theories of Descartes and Gassendi. He considered that matter was composed of corpuscles of different shapes, sizes, motion or rest, and solidity.
or impenetrability that are created by God. The four elements of Empedocles (earth, air, water, fire) or the three principles of Paracelsus (mercury, sulfur, salt) were not regarded as elements by him because he did not consider any of these to be fundamental constituents of existing bodies. However, he did not describe any elements. He exerted an extremely important influence on the development of chemistry as a science in the seventeenth century (46).

The prominent physicist, Sir Isaac Newton (1642-1727 CE), was also an alchemist. His theory of matter was in agreement with the atomism of Epicurus and Boyle including the existence of the void. In Query 31, Book 3, of *Opticks*, he wrote “All these things being consider’d, it seems probable to me, that God in the Beginning form’d Matter in solid, massy, hard, impenetrable Particles, of such Sizes and Figures, and with such other Properties, and in such Proportion to Space, as most conducd to the End for which he form’d them” (47). God's continual presence was also necessary for their continued existence. Newton assumed that the forces in corpuscles were not only gravitational but also had electrical, magnetic, attractive, and repulsive components (48).

Ruggiero Giuseppe Boscovich (1711-1787 CE), a Jesuit priest, replaced corpuscles with force-atoms (1758 CE) or point-centers of alternating attractive and repulsive forces. The views of Father Boscovich were similar to those of Newton, the Hindu atomists of the Nyaya-Vaisheshika, and the Arab followers of the Kalam (49).

The Russian atomist, Mikhail Vasilyevich Lomonosov (1711-1765 CE) believed that changes of matter were due to the motions of constituent particles. The particles consisted of “elementa” that contain no smaller bodies of different kinds. If a corpuscle (a small mass consisting of aggregates of elementa) consisted of the same elementa, it was homogeneous. If the components of the corpuscles were different elementa, the corpuscles were heterogeneous (50).

Bryan Higgins (1737 or 1741-1818) applied Newton’s repulsion of atoms in air to simple and compound gases, and suggested that there were caloric atmospheres around molecules of compound gases (51). Many of his ideas were promoted by his nephew, William Higgins (1762/3-1825), who anticipated parts of Dalton’s atomic theory and law of multiple proportions in 1789 (52). In 1814, he wrote (53):

> These considerations gave birth to that doctrine which Mr. Dalton, eighteen years after I had written, claimed as originating from his own inventive genius. What his pretensions are will be seen from the sketches which will soon follow, and which have been taken from my book.

A controversy ensued concerning the awarding of credit with Dalton being remembered rather than Higgins (54).

In 1789, Antoine-Laurent Lavoisier (1743-1794 CE) published a *Table of Simple Substances* (p. 175-176) in his book *Traité élémentaire de Chimie, présenté dans un ordre nouveau at d'apres les découvertes modernes*, (55). The subtitle to the table was “Simple substances belonging to all the kingdom of nature, which may be considered as the elements of bodies”. None of the four elements of Empedocles (earth, air, water, fire) or the three principles of Paracelsus (mercury,
sulfur, salt) were included except for caloric one of whose old names was fire. On page xxiv, he wrote that "if by the term elements, we mean to express those simple and indivisible atoms of which matter is composed, it is extremely probable we know nothing at all about them." Thus, the Ancient Regime of Alchemy was overthrown, and the science of chemistry replaced it.

In ancient India and Greek lands, a notion of atoms Philosophical chemists were making After Aristotle, they were ceasing Alchemy or the ancient régime II was beginning Little were alchemists adding Until chemistry, chymistry replacing The atoms of Dalton were besting

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