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THE CONCEPT OF MATTER AND ITS STATES IN INDIAN LITERATURE

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INTRODUCTION

Religion in India is a rational synthesis which is experimental and provisional in its nature, attempting to keep pace with the progress of thought. The sages of yore were seekers after truth and so is the modern scientist. The difference between the two is that the sages explored both within and without, while the modern scientist is invariably busy to achieve the above objectives with the objective world, finding new vistas of immense dimensions. The *ṛṣis* on the other hand found out with their subjective penetration an intimate relationship between the truth and the daily life of people, so much so that an approach to spiritual realisation became a way of life for them. Their ultimate scope was to support the theory of *māyā* and their only desire was to establish the existence of one supreme consciousness. But as they saw that the man, given to the pursuit of internal objects, could not all at once penetrate into the highest truth, they held out to him a variety of thoughts as propounded by the six important systems based supposedly on the vedas. They are *Vaiśeṣika*, *Nyāya*, *Sāṅkhya*, *Yoga*, and the dominance of interest in the subjective sciences in the two *mīmāṃsā* does not preclude their interest in objective sciences. It was their synthetic vision that made Indian philosophy comprehend several sciences which have become different in modern times. Their intellectual impulse extended to logic and grammar, medicine and astronomy, and in fact to all arts and sciences ranging from architecture to zoology. Their positive achievements in sciences cover a vast field, viz. mathematics, measurement of land, mapping out the heavens, tracing the course of sun and the planets through zodiacal belt, study of birds, beasts, plants and seeds and the constitution of matter. They studied the various states of matter and its properties, developed the concept of the origin of electricity, atom and its strncture. They were also not lacking in technology which is borne out by the two epics. But as stated earlier, their scientific and philosophical way of study and research aimed at right living and communion with God, the supreme consciousness. So their studies were restricted to those fields which helped them to achieve the above objectives.

Of late, efforts have been made to evaluate the works of Democratus[1], Newton[2] and Priestley[3], but very few have an insight of the vital role played by the Aryan scientists.

Newton set forth an elaborate theory of matter which included the assignment of a complex hierarchical internal structure of matter and the postulation of the

existence of various forces associated with the particles of matter. Later, he realized that the material particles were in themselves passive and were acted upon by the particles of ether, the force originating from the particles of ether.

This is the same concept as that of Vedic *Prakṛti* (primordeal matter) which represents energy as *avyakta* and matter as *vyakta*.

Priestley stated "The architect of the universe and of our being has disposed all things in harmony with one another. It is required of us, therefore, to see each part of philosophy in its connection with the whole grand design.

I am aware that it has been a fashion of late to separate chemistry from natural philosophy.

The laws of chemistry are finally to be resolved into knowledge of insensible particles of which matter is composed and the laws of attraction and repulsion which, as Sir Isaac Newton showed, are the great desiderate of natural philosophy."

The great Indian sages, working scientifically and logically, awakened their *ṛtambhara prajñā* (purest intellect) to understand the real nature of the truth and thus discovered the self.

According to Beneridge, "Elaborate apparatus plays an important part in science of today, hut I sometimes wonder, if we are not inclined to forget that the most important instrument in research must always be the mind of man."

Wilson[4] states, "We have no way of acquiring the inborn wisdom which is most responsible for their success, but there are a few techniques which we can learn from them". The modern scientist, in the pursuit of truth, is trying to recognize and control the world of objects. It is imperative for us, as propounded by *ṛṣis*, to organize ourselves to get the maximum advantage of the arrangements brought about by the modern scientist.

The ancient men of wisdom not only propounded the philosophy, but also prescribed the proper technology to achieve the desired aim. In this pursuit, they did not ignore the study of matter, but their enquiries were confined to the fields which helped them to understand the self.

Much of the knowledge acquired from these pursuits is contained in the four *Vedas*, various *Upaniṣads*, and books written by the disciples of the schools of Kaṇāda, Gautama and Kapila. The names of Nāgārjuna, Caraka, Suśruta and other Buddhist and Jain thinkers are worthy of mention. Since all the works of these sages have been written in Sanskrit and Pali, the efforts of persons from Max Muller, Whitney and Raja Rammohan Roy to Arabinda Ghosh, who have tried to interpret them, are creditable.

But P. C. Ray, Gamow, Wilson, Basham, Meaterlink and Satya Prakash are some of the eminent persons who have made an effort to evaluate and place the scientific aspect of the thoughts of the sages before the modern world.

The *Vaiśeṣika*[5] and *Sāṅkhya*[6] systems are the earliest documents that expose the constitution of matter and associated hypotheses. The remarkable exposition of the *nyāya-sūtra* of Gautama[7], the *Vaiśeṣika darśana* of Kaṇāda, and the *Sāṅkhya* philosophy of Kapila explain not only the methodology of science, but also explain the physics and chemistry of matter.

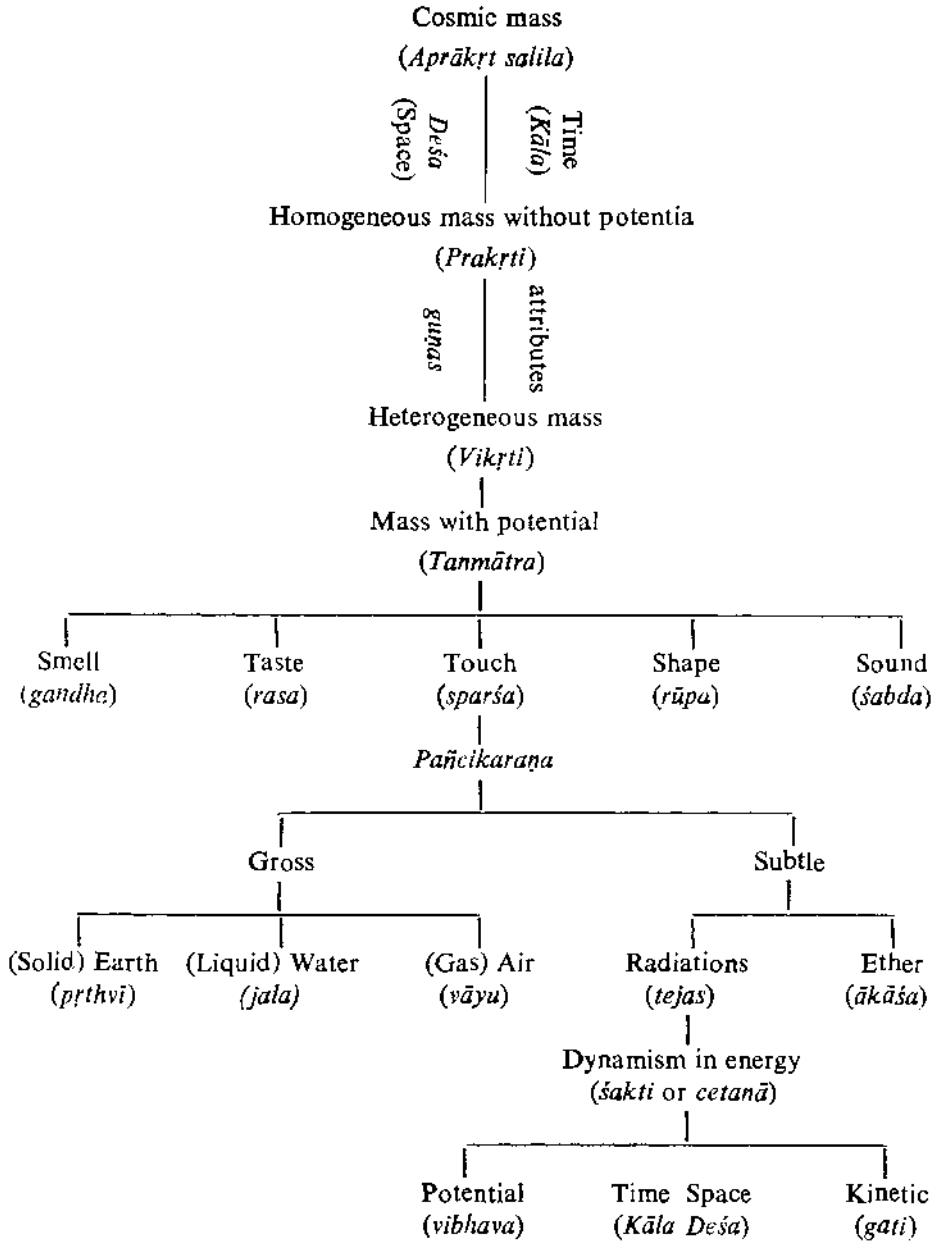
The *Sāṅkhya* system deals not only with the principle of cosmic evolution in metaphysical terms, but also describes evolution in terms of modern physics covering the principles of conservation, transformation and dissipation of energy. It also elucidates the preatomic state of matter.

Classification of matter

The study of matter is facilitated by adopting some scheme of classification which brings some order into its otherwise complex behaviour. Therefore, the following scheme has been worked out to give a concept of the formation of matter from the cosmic mass.

Cosmic mass, the *puruṣa* or *aprākṛt salilum*, is a highly compressed point source and has the attribute of expansion and contraction, a simple harmonic motion with a very large period. This on expansion gives *prakṛti* which has three *guṇas*, power of existence (*sattva*), power of attraction or combination (*rajas*) and power of separation (*tamas*), in equipoise. This is nondiscriminating (*avivekī*), object (*viṣaya*), common (*samāna*), non-intelligent (*acetana*) and productive (*parasvadharmī*). This gives rise to intellect (*buddhi*) and selfsense (*ahaṅkāra*) on the one side and mind (*manas*) and five senses on the other side (not shown in the chart). Intellect and selfsense, which is a heterogeneous mass (*vikṛti*), give rise to five *tanmātras*, the formation of which is given in Figs. (1-5). The selfsense or *bhūtāde* with the cooperation of *rajas* develops vibrations which are responsible for producing sound, as shown in Fig. (1). When this homogeneous vibratory medium breaks up into clusters, it produces impacts, which give rise to touch *tanmātra*. These impacts in sufficient quantities generate radiations which give rise to form (*rūpa*) *tanmātra*. Now these systems are at different temperatures, which give rise to taste *tanmātra*. The taste with all other *tanmātras* gives rise to smell *tanmātra*.

After the formation of *tanmātras*, the *pañcīkaraṇa* takes place as explained in Fig. (6), and the atoms of *ākāśa*, *vāyu*, *tejas*, *jala* and *pṛthvī* are formed. Figs. (1-5). It is essentially a phenomenon similar to the formation of elements of the Periodic Table. When the *tanmātra* of touch penetrates the core of *ākāśa*, the new atom of *vāyu* (gas) is formed as a positive charge by penetrating the electron cloud giving rise to the next positive ion of the Periodic Table, which becomes neutral by electron capture.



Solid (*Pṛthvī*), depending on the composition and configurations of its atoms, assumes different states. Solids can be classified as: Plastic (*Sughtya*), Glass (*Kāca*), Crystalline (*Maṇi*), and Amorphous (*Amṇibh*).

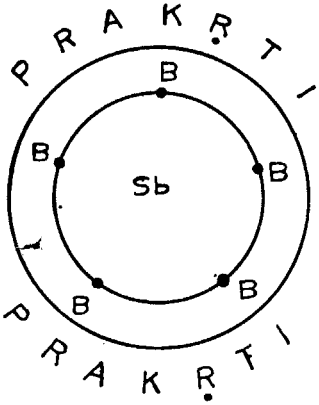


Fig. 1. Atom of *Ākāśa*

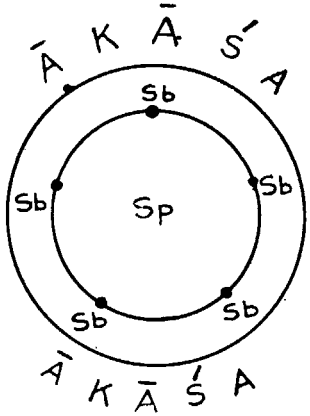


Fig. 2. Atom of *Vāyu*

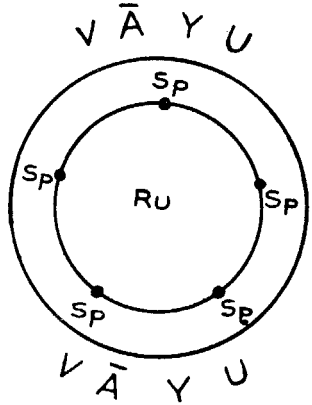


Fig. 3. Atom of *Teja* or *Agni*

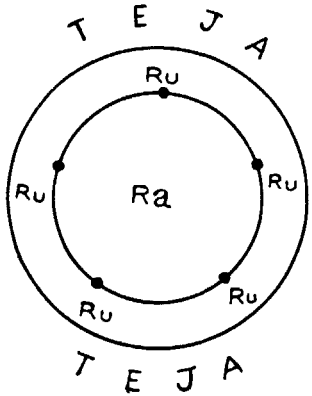


Fig. 4. Atom of *Jala* (liquid)

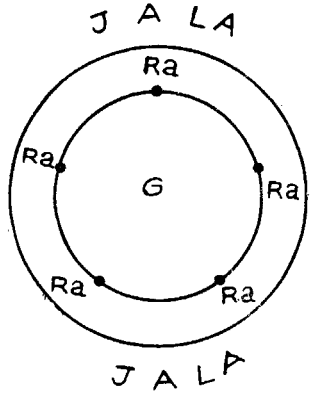


Fig. 5. Atom of *Pṛthvī* (solid)

Explanation of terms in Figures 1—5

B = *Bhūtāde* (Super subtle matter)
Sb = *Śabda* (Vibrational potential, sound)
Sp = *Sparśa* (Impact potential, touch)
Ru = *Rūpa* (Light potential, form)
Ra = *Rasa* (Taste)
G = *Gandha* (Smell)

According to the Vedic concept, the universe consists of *Puruṣa* and *Prakṛti*; the latter is the energy and matter of the modern scientist. Many speculations have been made about its ultimate nature, but they have failed to satisfy the curiosity of an enquiring mind. It is a unit of experience, an objective reality, but it is not possible to precisely state what it is. It is, in reality, an undifferentiated manifold and indeterminate infinite continuum of infinitesimal reals characterised by three attributes: (*i*) the state of equilibrium, (*ii*) energy, and (*iii*) mass or inertia. So, at best we can study its variety and learn all about its attributes, but it is something which is not permanent and is continuously undergoing change. It is matter outside and energy inside. According to Chardin,[8] "In the eyes of the physicist, nothing exists legitimately, at least up to now, except the without of things. Finally, it breaks down completely with man, in whom the existence of a within can no longer be evaded, because it is the

subject of a direct intuition and the sub-stratum of all knowledge. In every region of space and time, coexisting with their without, there is a within. According to Vedic seers, matter is the manifested self (*Pratyak's caitanya* or *Pratyak's Tattva*), whereas energy is the unmanifested self (*Māyā* or *Śakti*). The first is the inactive state and the action state of supreme reality, a concept which is very near to Einstein's theory of relativity, which enumerates inter-convertible nature of matter and energy. Since we cannot give its absolute definition, it would be safe to define it by its attributes. Anything that has mass and occupies space can be defined as matter. The basic changes in matter are brought about by energy.

Types of Matter

There are various states of matter, depending upon its properties. The particle size is of paramount importance in describing the type of matter. Matter can be broadly classified as (*i*) Manifested, i.e. *Vyakta*, and (*ii*) Unmanifested, i.e. *Avyakta*.

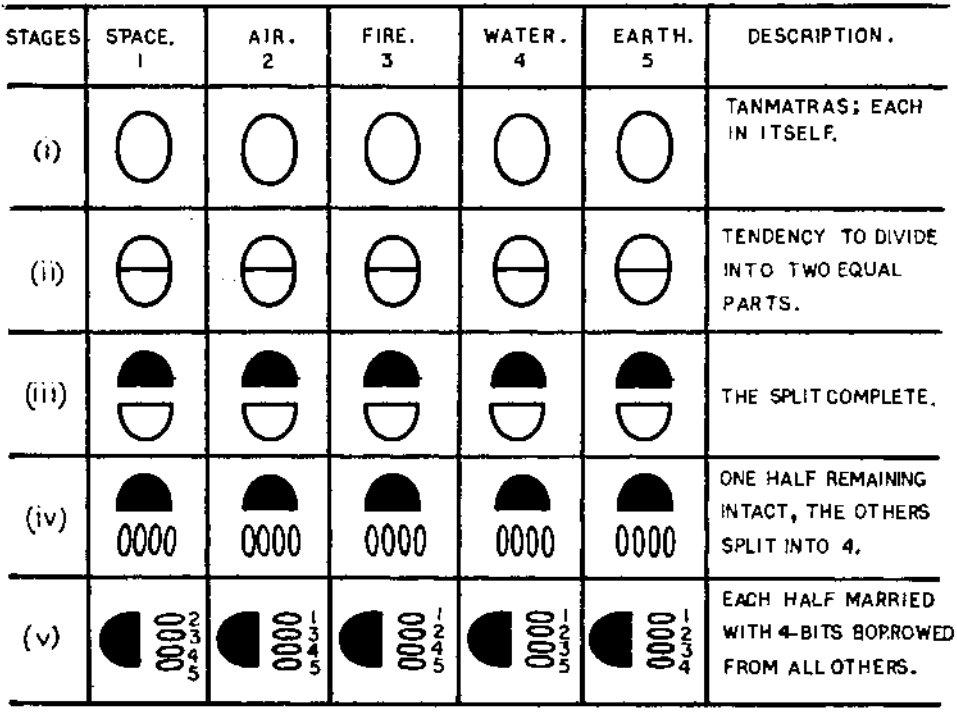


Fig. 6. *Pañcikaraṇa.* The process of pentamerous self-division and mutual combination.

Everything that can be seen by the naked eye is taken to be manifested, e.g. wood, silver, water, oil, fire, etc. Things that cannot be seen, but can be felt by the sense organs represent unmanifested form of matter, e.g. sound, smell, taste, air, electricity, etc. But there is always a continuous change from one state to another (Table I below).

TABLE I

Object	Dimensions in mm.	Method of detection
Plant cells	10^{-4}	Microscope
Blood (red) cells	10^{-4}	Microscope
Gold sol	10^{-5}	Ultra-microscope
Virus	10^{-7}	Electron microscope
Fine particles	10^{-13}	X-rays and electron waves

The density of matter in interstellar space (*marīchi*) and in the satellite has also been measured. The presence of hydrogen, helium and sodium has been detected in distant planets by spectral analysis. Vedas have referred to three types of energies, viz. heat, light and electricity. *Agni*, sun and *Indra* are considered to be the sources of heat, light and electricity respectively.

Therefore, there exist particles right from those that can be seen by the naked eye to those which can be observed only by indirect methods.

Energy

This is known as *apratyakṣa Brahma*. It has quantum and extension. It can be defined as the capacity to do work and overcome resistance. This has been discussed under *karma* (action). Qualities that continue to exist are called *guṇa*, while those which cease to exist are called *karma*. Actions having *sāttvik guṇa* will have potential energy, while those having *rajas guṇa* will have kinetic energy.

Kaṇāda[9] propagated the theory of sound. According to him, light and heat are only different forms of the same essential substance.

Types of Energy

There are two types of energy: (*i*) potential, and (*ii*) kinetic. Potential energy is there in a substance by virtue of its position from a standard datum or due to the arrangement of particles in the matter. In a waterfall, water flows down and loses its potential energy. The kinetic energy is due to motion, i.e. change in position. When we throw a particle up, its kinetic energy decreases as it goes up and is converted into potential energy. The potential energy is maximum when the kinetic energy becomes zero, i.e. the particle becomes stationary. Then it falls down freely, whereby potential energy is converted into kinetic energy. As a matter of fact, this process is a function of space and time (*deśa* and *kāla*).

Properties of Matter

The characteristics which permit distinction between two types of matter to be made are called properties. Characteristics like shape, odour, taste, smell, touch,

sound, weight, etc. are called attributes (*guṇas*) or reals. Other characteristics like density, fluidity, hardness, melting point, solubility, surface tension, etc. are termed as physical properties. Characteristics like the ability to interact with other substances, e.g. interaction between air and iron, i.e. oxidation of iron, fall under the category of chemical properties. The *bhasmas* of metals were well known to the sages.

Physical change is defined as one in which the substance changes its form or state, but retains its identity. It is easily reversible and no new substance is produced. Chemical properties remain unaltered, e.g. melting of ice to water.

Chemical change is defined as one in which the substance loses its identity, producing new substances in its place. It is not easily reversible and properties are altered, e.g. rusting of iron.

Types of Properties

Vaiśeṣikas have broadly classified properties as general (*samāna*) and particular (*viśeṣa*). The property that resides in many things is called general (*sāmānya*), e.g. fluidity (*dravatva*), measure (*parimāṇa*), downward flow (*spandana*), unctuous (*snigdha*), porous (*sauṣirya*), etc. But the wax becomes fluid on heating. Thus the fluidity in wax is a causal property (*naimitik*). It is eternal (*nityam*), one (*ekam*) and resides in all objects of its class (*svaviṣayasarvagatam*) with an identical nature (*abhinnalmakam*) and cause of the motion of concordance (*anuvṛttipratyayakaraṇam*). The particular (*viśeṣa*) property allows things to be perceived as different from one another. Each simple substance has a quality which makes it distinct from others, e.g. atoms, time, space, *ākāśa*, viscosity, osmosis, surface tension, *bhasams*, *rasas*, etc.

The generality has been categorized as dynamic (*par*) and static (*apar*). The dynamic generality (*par samāna*) is found in existence (*sattva*), motion (*chalatva*) chemical reaction (*pāk*), burning (*dāha*), etc. while the static generality (*apar samāna*) has been found in density (*gurutva*) unctuous (*snigdha*), matter is solids, etc. *Vaiśeṣikas* call the physical properties as *sāmarthya* and chemical reactions as *upakaraṇa*. Terms like *pāka* or *maraṇa* have also been used for chemical reactions. *Nyāya* believes that in a chemical reaction, substances first disintegrate to atomic state and then combine to form new compounds. This phenomenon is known as *pitu pāka vāda*, which is similar to the modern concept of ionic bonding. In the case of *pidhara pāka vāda*, it is not essential that matter should decompose to atomic state; it can form compounds otherwise also, like the covalent bond, hydrogen bonding and bonding by Vander Waals forces.

Suśruta prepared several compounds into two forms known as *antardhūma* and *bahirdhūma* which were the two resonance products of the same compound.

Ṛg Veda also describes unit process like extraction, filtration, concentration and distillation in the preparation of some *rasa*.

Table II gives some important physical and chemical properties.

TABLE II

Physical			Chemical		
Vedic term	English term	Example	Vedic term	English term	Example
parimāṇa	measure	ml, kg.	*samyoga*	conjunction	formation of molecules from atoms
dravatva	fluidity	liquids or gases	*vibhāga*	disjunction	breaking-up of molecules into atoms
visyanda	liquifaction	steam with water	*bhasma*	oxidation	gold oxide
gurutva	density	lead particle chopping	*rasa*	sulphide formation	mercury sulphide
vega	acceleration	gravity	*pāka*	digestion	food in stomach
spandana	downward flow	water	*dāha*	combustion	burning candle
snigdha	unctuous	oil	*kṣāra*	alkaline salt	java khar
sauṣirya	porous	pumice stone	*amla*	acid	acid of tamarind
syanta	viscosity	liquids	*lavana*	salts	salts of sodium
abhisarandah	osmotic pressure	water rising to leaves in a tree			
kaiśaprakriyā	capillary action	liquid rising in a fine tube			
nadana	an action which neither produces sound nor breaks the substance used but it continues	liquid rising in a jar under pressure			

Structure of Matter

To understand a physical or a chemical change, it is essential to correlate it with the ultimate arrangement of particles in space. According to *Sāṅkhya*[10], the structure of matter depends on the arrangement of its particles; through physical or chemical interactions of these particles within themselves or with one another, matter acquires individuality and variety. Sulphur on being heated and cooled passes through various allotropic modifications, depending on the temperature.

Types of Systems

Whenever the structural composition of a substance is the same throughout the space, it is called homogeneous, e.g. water, sugar and sulphur.

When the composition varies in space, it is called heterogeneous like granite, mica, etc. Some substances are very complicated in chemical composition and it is difficult to classify them.

Origin of Matter

The series of events through which the earth passed, in order to make its surface to become much as it is today, are the subject of many interesting hypotheses. The creation of the universe in the *Ṛgveda*.[11] terminology signifies its manifestation. The creation of the universe proceeded according to an order called *Satya* and the law called *Ṛta*[12]. There was no chance in the manifestation process, and it was governed by the universal law and order which also govern all changes. The Vedic sages[13] were aware of the speculations involved in unfolding the mystery of creation of the universe. *Nāsādiya Śukta*[14] comes closest to explicating the process of manifestation and expansion. It states that there was neither *asat*, the manifold chaos, nor *sat*, the first stage of material evolution from primordial matter, nor nebula, nor sky. There was primordial chaos—*arṇava* (ocean)—which covered all like a haze, involved in a huge and unbound collapse. Dort[15] suggests a disordered expansion in the initial stage and an ordered motion thereafter. Presumably, disordered motion is conducive to efficient mixing and ordered motion to inefficient mixing.

The earliest cosmic mass known as *aprākait salilam*[16] primeval atom (probably neutron or neutrino) was a highly compressed, extremely rectified and completely homogeneous mass maintained by convection currents, from which the universe started its evolution. The concept of *salilam* is the primeval nucleus of modern science, i.e., cosmic mass.

This state of the universe is described as "*Hiraṇyagarbha*" state in Vedas, which is the same as the present day nebula. There was no separate identify of anything in this state. Dixon[17] comments as follows: "The results indicate that the interstellar medium (*mārichi*) possessed a high degree of homogeneity at the end of the contraction phase".

A violent expansion (Big Bang) began accompanied by cooling as a result of radiation energy. But it was all a quantitative expansion, which became infinite with time. This was called *ākāśa* by the Vedic seers and space or ether by modern scientists. Afterwards, there was a qualitative expansion. The elements (*tattva*) began to form from neutrons (a neutron changes into proton and electron with the emission of energy). The attributes and properties of every object became manifest from unmanifest. As long as the universe was in the form of *Prakṛti*, there was no identity of the gross and the living (*caitanya*), but the moment it became *ikṛti*, every object started getting a separate identity, depending on its attributes. As per the *Vedic* concept, condensation of the elements around centres of turbulence in the process of expansion gave rise to clusters of matter, which finally resulted in *vāyu*, *agni*, *jala* and *pṛthvī*. All these five *tattvas* finally gave rise to sun, stars, planets, etc. With the passage

of time, expansion acquired qualitative form in place of quantitative, resulting in a *vikṛti* universe.

Kapila was the first to develop the scientific concept of *Prakṛti*. He considers it to be the primal originator of the universe. According to this concept, the universe was created because of physical and chemical changes. He states that in a chemical reaction[18], certain defined substances under fixed conditions yield well-defined results. There is always a definite relationship between cause and effect[19]. This is the law of conservation of mass and energy.

There was one element (*mahat*) in *Prakṛti* and all the multiplicity was dissolved into a unit. On expansion, there was also increase in the multiplicity. It is this multiplicity that manifested itself into five different elements (*pañca tattva*). Though *Kapila* thought *pañca tattva* as elements, actually they represent substances or compounds of modern age. *Kapila* and *Gautama* have described *ākāśa* (*ether*), *vāyu* (*air*), *agni* (radiations), *jala* (water) and *pṛthvī* (earth) as the five principal *tattvas*. According to them, matter is identified by the manifestation of the predominant attributes of this group.

Tanmātra

The five elements postulated by Kapila were latent in Prakṛti. Therefore, there was only the possibility of first a physical change and then a chemical change. The latent form of the five elements is known as *tanmātra*. According to *Sāṅkhya*[20], *Gautama* and *Kanāda*, smell, taste, form, touch and sound are the *tanmātras* of earth, water, fire, air and ether. These *tanmātras* were the elements of *sāṅkhya*, which ultimately rose to twenty-five in number. According to *Vyas*[21], due to action, intelligence and inertia, sound was produced and then sound, touch, shape, taste and smell combined together to make the molecule of *pṛthvī* (earth). As a matter of fact, the above are the attributes of *pṛthvī* (earth).

Vaiśeṣika believed in two types of elements—those that are in atomic state are perennial and others which are casual are time-bound.

Ākāśa

Akāśa was the first product in the process of evolution of the universe[22]. It is the ultimate stratum for the universe. The ether *ākāśa* defies a primary definition, as it implies vastness and immensity. It gives us a picture of uncertainty and forms the basis of the concept of location. It is here as well as there, it is inside as well as outside. Scientists of the nineteenth century used the word ether to describe the contents of space, but when they tried to understand its nature, they encountered so many difficulties that they abandoned its use. It again came back into use with an extended meaning in the twentieth century. Now it forms one of the two components of a new reality, i.e. continuum of which time is the other component. Both of them have no absolute reality in themselves, but are relative concepts. James Jeans[23] states "Nature

knows nothing of space and time separately, being concerned only with the four-dimensional continuum in wbich space and time are welded inseparably together into the product we may designate as space-time". To define an event in our experience means to define it in terms of space and time continuum in which all objects and entities melt into events. Any event in the scientific language is but a configuration of space-time.

According to *Iśa Upaniṣad*[24], it is inside everything and it is outside everything. It is one and indivisible, but it appears to be divided hy the passing events of the world of sense experience.

Agni (Radiations)

In the Vedic literature, the term *agni* is used for energy, specially heat energy or heat waves[25–28]. *Rg Veda* and other scriptures[29] state that with the expansion of the universe, there was interaction between the fundamental particles in space, so much so that the sun became effulgent. There was motion and stability. Modern science calls it the law of mutual stability due to heat waves. These waves have characteristic motion and move in group fields[30]. Being next to space in subtleness, they pervade everywhere and constitute the chief *tattva* of the universe. Since they were radiated by the sun[31–33], they had penetrating lustre. These groups or clusters on movement started producing impacts, and thus gave birth to impact potential which during the passage of time gave birth to *vāyu* (air) gross element. Solar system and the galaxy of stars move on the substances of *vāyu* and it appears as if they are woven by *vāyu* in the string.

Vāyu (Gaseous State)

Vāyu represents the modern gaseous state. It pervades everywhere, because it is next to *agni* in subtleness. It has become the chief element for all living organism.

Taittirīya Upaniṣad mentions *ākāśa*[34] (ether) as the source of *vāyu* (air). According to it, *ākāśa* is the stratum for all the *tattva* (elements). *Caraka*[35] believes *vāyu* to be an active and attributive principle. Its other attributes are touch, weight, measure, fluidity, motion, etc. *Aṣṭāṅga śarīra*[36] believes that in addition to the above, sound is also its attribute. According to *Chāndogya Upaniṣad*[37], *vāyu* has no colour. *Vaiśesikas* suggested that all the attributes of *vāyu* depend on the arrangement of particles or atoms or molecules as a result of forces of attraction and repulsion. Its common and most important attribute is touch. It cannot be seen, because its shape is *sam vāya*. The relationship between cause and effect is called *sam vāya*. In the modern concept, the gases are found to have properties like mass, thermal conductivity, specific heat, viscosity, effusion, kinetic energy, mass transport, etc. At low pressure, they have been found to conduct electricity.

Jala (Liquid State)

In the cosmic expansion[38,39], with the interaction between fundamental particles in space, a fluid state is generated which may be termed as *salila* (liquid). This fluid

state, with the help of *agni*[40], brings about more and more physical and chemical interaction, with the net result that convection currents called *vāyu* are generated. These heat radiations in the fluid state brought about *jala*. Thus, *vāyu* is considered to be the binding medium between earth and water, and water as the binding material between fire and sun.

Aitareya Upaniṣad[41] has also referred to *ambhas*, i.e. subtle steam and water. *Chāndogya*[42] gives the colour of water as white. *Caraka*[43] has given its attributes as taste, fluidity, coldness, viscosity, unctuous, slow, soft, moist, union and liquifaction. *Aṣṭāṅga śarīra*[36] gives its attributes as taste, steam, sweat, wetness, fat, blood, semen, urine, looseness and oily. According to *Nyāya*[44], its important attributes are touch, sound, shape, taste, number, measure, separateness, combination, division, priority, posterity, motion, fluidity, density and viscosity. *Vaiśeṣikas* feel that the general property of water is fluidity, but ghee (fat), shellac and wax become fluid under the influence of heat; so this is not their natural attribute but an effective (*naimitik*) property. Water is cold to touch, falls down because of density, flows on a surface because of fluidity and rises because of the heat of the sun (evaporation), or in contact with a tube or air (surface tension). Because of some latent power (osmosis and capillary action), the water poured on the roots of a tree rises to the leaves. It also rises in conjunction with air and by *nodanam* (compression). In union with light or heat, it becomes either dense or thin. The particles of water suspended in the atmosphere become the cause of lightning and thunder in the atmosphere. *Nyāya* considers water as atomistic and causal. The causal water is the constituent of body, sense and desire. According to *Vaiśeṣika*, all its attributes depend on the arrangement of its atoms and small particles which is the same as the modern concept of either imperfect gas or imperfect crystal.

Pṛthvī (Solid State)

It covers all crystalline, amorphous, powder, glass and plastic states. *Taittirīya Upaniṣad*[40] believes that *pṛthvī* has evolved from *jala* (water). *Aitareya Upaniṣad* considers it the grossest of the *pañca bhūtas* (five elements). According to *Chāndogya Upaniṣad, pṛthvī* (earth) is the *rasa* of gross elements and is associated with black colour. *Vaiśeṣika* school gives its attributes as sound, touch, colour, taste, smell, and hardness. *Caraka* gives its attributes as heavy, static, extensive, dense, gross and smell. *Nyāya* believes that the earth has attributes like touch, number, measure, separateness, conjunction, disjunction, priority and posterity, movement, colour, taste, smell and density. *Praśastapāda*[45] considers *saṃskāra* also as one of the attributes. According to them, there are six tastes, two smells and the attribute of touch depends upon heat. These are also of two varieties—hot and cold. They take it to be *nitya* (eternal). Jaina[46] thinkers view it as very gross, because it cannot join or disintegrate by itself. *Vaiśeṣika* considers it to be of two types, one being the atomic state, which is eternal and the other, the active state which is ephemeral. It has special attributes like throwing up, throwing down, contraction, expansion and motion. The action in it is brought about by addition, composition or velocity.

The following inferences can be drawn from the above regarding solids:

1. They have a definite shape, mass and volume.
2. They have colour and smell.
3. They are hard and have low compressibility.
4. They can neither disintegrate nor join by themselves.
5. They conduct heat.

Vaiśeṣikas feel that all the above attributes depend on the arrangement of their *paramāṇus* (atoms), which, in turn, depends on the attractive and repulsive forces between them. This is the modern concept of solid state which explains the crystalline, amorphous, glassy and plastic states of solids.

Solution and Colloidal State

The great *ṛṣi* Uddālaka Āruni[47], in order to illustrate the oneness of the self to his son Śvetaketu Aruneya, asked him to bring some water in a container and put some salt in it. He asked his son to see him next day. The next morning he said to him "That salt you placed in the water last evening, please bring it hither". Having looked for it, Śvetaketu could not find it, as it had dissolved. Then the *ṛṣi* asked him to take a sip from this end and he found it saltish. Then he further asked him to take sips from various portions of the solution and Śvetaketu always found it saltish to the same extent. Then the great priest explained to the pupil that he did not perceive the salt being there in the solution, although it was there all the time.

The above story not only explains that salt is soluble in water, but goes further to say that the solution so formed is also homogeneous. The object of this story is not only to explain where the salt has disappeared but also to explain why and how it has disappeared.

Types of Solutions

There are two major types of solutions—homogeneous and heterogeneous. A homogeneous solution is one whose composition either remains uniform and constant or uniformly varies throughout its entire volume, e.g. air and milk. A heterogeneous solution is one whose composition varies from place to place, e.g. river water.

These can be further divided into three types, depending upon the particle size of the solute: (1) coarse dispersion, (2) colloidal dispersion, (3) molecular dispersion.[48–49]

The *Nyāya-Vaiśeṣika* system in *arambhuāda*[50], has made it clear that all matter consists of *paramāṇus* (atoms). They have also visualised the size of *paramāṇu* as one-sixth part of the smallest dust particle which is visible in the rays of the sun coming from a ventilator. According to *neemt* measurements, the shortest dust particle is of the order of 10 μ, i.e. 10^{-6} cm. One-sixth of this will be 1.6×10^{-7} cm. which is very close to the size of the modern atom. *Nyāya* believes that *paramāṇus* have shape

and as such can combine to form *aṇus* and other particles. Two such *paramāṇus* from one *duyānu* (molecule) and three *duyāṇus* go to make one *tresareṇuka* (a colloidal particle) and four *tresareṇukas* form one *catureṇuka* (coarse particle) from which the creation[51] proceeds.

Ṛṣis of *Purvamīmāṃsā*[52] school have also postulated *paramāṇu*, but their *paramāṇu* is like a dust particle which can be seen and which is actually a coarse particle.

The coarse dispersion (*catureṇuka*) is one that has a particle size of the dispersed phase greater than 10^{-4} cm, e.g. river water containing suspended particles. The particles can be removed by filtering it through a filter paper and can also be observed either with the help of a microscope or as such. They cannot diffuse.

Colloidal State

The term colloid means glue like substances. Previously, it was applied to all those substances in solution which do not pass through semi permeable membrane. Later, it was established that anything can be obtained in colloidal state.

A colloidal dispersion has a particle size between 10^{-4} and 10^{-7} cm (1 μ-1 mμ), e.g. smoke, milk, gums, etc. It passes through a filter paper, but not through ultrafilter paper. The particles cannot be seen by a microscope, but can be seen by an ultramicroscope or an electron microscope. The solution slowly diffuses through a dialyzing membrane and contains charged particles called micelles. It can also be ionic in character.

A molecular dispersion (*duyāṇus*) contains dissolved particles smaller than 10^{-7} cm (1 mμ). The particles pass through both the filter paper and ultrafilter paper. They cannot be observed even by an electron microscope. They freely diffuse through the membranes. They are normally not charged unless they dissociate into ions. The best example is normal drinking water which contains dissolved salts.

The phenomenon of cosmic evolution is characterised by activity, change or motion (*parispanda*). Therefore, interaction of substances in different states gives rise to colloidal (*kalil*) products as given in Table III.

It is not possible to classify the ninth system, as it can be treated either as a mixture or as a solution. In solutions, apart from diffusion, other forces already discussed come into play, say the forces of cohesion and adhesion. Generally, any gaseous mixture at equilibrium is treated as a solution.

In colloidal dispersions, the solute is either partially soluble as gums, etc. or wholly insoluble, as gold in water. Stable suspensions can be made only by reducing the particle size to the order of 10^{-5} cm, when the particles remain suspended in the

TABLE III

Sl. No.	Dispersed Phase	Dispersion Medium	Name of Colloid	Example of solution	Example of colloid
1.	solid	solid	solid sol	brass	gems *(ratna)*
2.	liquid	solid	gels (*silsi*)	amalgum	opal, *vaṃsalocana*
3.	gas	solid	solid foams	H_2 in Pd	lavas
4.	solid	liquid	sol. (*vilya*)	syrup	goldsol
5.	liquid	liquid	emulsion (*payas*)	kerosene oil	milk, cream
6.	gas	liquid	foam (*phena*)	soda water	froth in beer
7.	solid	gas	solid aerosol	camphor in air	smoke *(dhūmra)*
8.	liquid	gas	liquid aerosol	water vapour	clouds (*ambhas*)
9.	gas	gas	soluble in all proportions	air	—

dispersion medium and baffle all efforts to separate them by the usual means of separation[53].

Glassy State

Glass is a transparent, hard, rigid and brittle material. It can be both inorganic and organic. Interest in its development dates back to Indus Valley Civilization. During 1600 B.C. glass industry became an advanced cottage industry in India, manufacturing glass beads, bangles and small bottles of beautiful designs to hold essential oils.

It is obtained by supercooling liquids, but it can also be formed by the condensation of vapours[54]. The properties of glass formed under the two systems need not be the same.

Glass on heating continuously softens and then melts. In some liquids, the force of attraction between the molecules is so strong even above the freezing point that they cannot move freely and do not provide a suitable nucleus for crystallization. So the liquid is supercooled. The individual atoms or molecules[55–57] are in an ordered array over a short range, but there is no long range order. The molecules in the glassy state[58] oscillate about their equilibrium position and then interchange of their places either does not occur at all or only very rarely. When most of the motion is frozen with decrease in thermal energy, it leaves the liquid in a random and disordered state; a solid state results, which is known as the glassy state. The glassy state represents the metastable state of order of a liquid which is frozen (supercooled) and preserved at a lower temperature rather than a specific kind of material state. Such organic or

inorganic substances are known as glass, e.g. perspex, polystyrene and salts between elements of Group VI and elements of Groups III, IV and V.

Plastic State

There is no product as widely used in every sphere of life as macromolecules. The earliest reference to the term resin implies natural materials produced by vegetable or animal life, e.g. shellac. A reference to *lac*[59] is found in *Atharva Veda* and its use as a moulding material is given in *Mahābhārata*. As a matter of fact, the word shellac is derived from *silāci*[60]. The macromolecules comprise the most widely distributed material in the universe in the form of carbohydrates, cellulose, proteins, rubber, etc.

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