blood in the chyle, acted on again by Vāyu (biomotor current) and the fat-forming metabolic heat (धर्मता) in the menstruum of lymph (प्ररुक्तित्व), receives viscosity and whiteness, and produces the fatty tissue, the Earth-compounds and Ap-compounds of the food especially contributing to the product. This fat in the chyle (or blood), or rather the grosser part of it replenishes the fatty tissue of the body, but the finer essence of fat in the flesh in the blood in the chyle, acted on by Vāyu (biomotor current) and the marrow-forming metabolic heat, in the menstruum of lymph (संक्षम). becomes hard (or crystalline), and forms bone, the Earth, Vāyu and Tejas compounds contributing principally to the product. The essence of the fat fills the hollow channels of the bones, and acted on again by biomotor Vāyu and metabolic heat, becomes transformed into the marrow. The marrow is transformed into the semen, which is conveyed down by means of a pair of Dhamanis (ducts) (इंधमणि), lodged in its receptacles (संतत्राव—प्रकवि) and discharged by means of another pair of ducts (इंधविषनव). The semen, or rather all the elements in their finer essence, give off Ojas, which returns to the heart, the receptacle of chyle and blood, and again floods the body, and sustains the tissues, thus completing the wheel (or self-return-
ing circle) of metabolism (चरित्रिक्ष चक्र, Cf. Charaka and Vagbhata).

It is to be noted that, throughout, the fluid in the chyle (or blood) acts as the menstruum, though occasionally the lymph, which is itself a derivative from the chyle is added as in the case of the fatty tissue and the marrow; and that each preceding element or constituent of the body (चाल ऋणस्तर), takes up the proper organic compounds from the food-chyle to form the next element or tissue. Throughout also, the chemical changes are due to the metabolic heat which breaks up the compounds and recombines, but the operations and even the vehicles perhaps of this heat are different. For example, these heat-corpuses in the biliary ducts produce the bile, but the bile secretion is supposed to contain two distinct substances, (1) a digestive fluid in the duodenum (वृक्षेप) which acts on the chyme to produce the chyle, (चाल ज्वल वाढङ्कः विन्यासः); and (2) a coagulating bile-substance in the liver which adds a red pigment to the chyle and transforms it into blood (व्रत विन्यास). Besides, there are three other biles, of which the aqueous humour in the eye is supposed to be one (याकायस्थ क्षडः) helping in the formation of visual images (कथानिशिप्त). This is the view of Dharmasaï and his school, but Atreya holds there is no
evidence that the bile really performs the first (digestive) function, for this can be accounted for by the animal heat arising from the working of the whole bodily machine. There are three different hypotheses regarding the course of metabolism and the successive transformations of the chyle (चोदशिन्यन—वेदाचिन्यन—सत्त्रस्थिन्यन वपत्राचिन्यन्यन्यनिति फळ्या वाल्मीकिन्यन) Chakrapāṇi, Bhānumati, Sūtra-
sthāna, Chap. 14, Sūtra 10; also his commentary on Charaka, Sūtra-sthāna, Chap. 28), but my account is based upon the second hypothesis which has the preference of Chakrapāṇi (क्षर्व). It may be added as a curiosity that each element of the body (अयु) under the metabolic heat is supposed to give off a finer essence (शूक्लायु) which serves as the material of the next succeeding element, and a drop (सृष्टि), which forms some of the secreta in the body, (including the nails, the hair, etc.), besides retaining its own substance (the gross or main part) which is driven along by the Vāyus (biomotor or vital currents) or by the Srotās to its destination in the body. Some idea of circulation appears to have been entertained, for the heart which receives and then sends down the chyle through the Dhāmanis gets it back transformed into blood, and the Ojas also proceeds from the heart and returns to it along with the chyle and blood. (Cf. Vāgbhāṣyamānī, तृतीया विषयमानी जीयान;
चविन्धुराक्षः। पवित्राक्षं हैं चात्मः प्राचीनविविधः। विपकः पवित्र बनवनुपन्त वानिधीकृतं बेदः। Susruta, Sūtrasthāna, Chap. 46. Cf. also बनकाबृहत्तमान। दशिनामृद्वीति पादपः खालिष्टेन बुधृखः तेन पितामुद्रीवं ते। ibid., Chap. 41. शौचालयप्ति वायुः येषोऽखः वधास्यः,
वंशाधराधीनः क्षान् क्षान् पार्थिवाधीनः पवित्राधीनः। चविन्धुराक्षः ते च युक्तम् पश्चा धृतयुपाधी दक्षः, पार्थिवा: पार्थिवाधीनः येषा: येषां र्षेगानाः। चविन्धुराक्षः तथा तथा भवेद्भैर्ये द्र पार्थिवा:। वेदवस्यां भुक्कारुषं द्रविधविनिविषयां परस्मायै। Charaka, quoted by Dalvana. चाही चविन्धुराक्षस्य च धुरुत्वीयस्य बोधेतु, फेरोपुरल वर्ष बासं विदास्माक्षां तत:। दशिनामृद्वीति पवित्राधीनः पार्थिवाधीनः पीताः पार्थिवाधीनः। चविन्धुराक्षस्य च धुरुत्वीयस्य बोधेतु, फेरोपुरल वर्ष बासं विदास्माक्षां तत:।

चविन्धुराक्षस्य च धुरुत्वीयस्य बोधेतु, फेरोपुरल वर्ष बासं विदास्माक्षां तत:।

चविन्धुराक्षस्य च धुरुत्वीयस्य बोधेतु, फेरोपुरल वर्ष बासं विदास्माक्षां तत:।
Charaka—Dridhabala Samhitā, quoted by Aruna in his commentary on Vāgbhata. भवा वेदांतिनिधव युक्तवं प्रवाचया
वेदांतिनायांविविधम्, भवा यज्ञ एव प्रथवो रक्तः स्नाययः। ततो रक्तभुगांत बन्यवाग्यां रक्तस्वस्वव्यां च चानुमयः। यज्ञः रक्तभुगांत बन्यवाग्यां बन्यवाग्यां यज्ञः बन्यवाग्यां बन्यवाग्यां बन्यवाग्यां
गतो रक्तभुगांत बन्यवाग्यां बन्यवाग्यां बन्यवाग्यां बन्यवाग्यां
(Chakradatta, Bhānumati). This passage shows that
the ‘venous blood’ was conceived to be chyle-
essence mixed with blood, and that the circulation
of the chyle so far as it was held to contribute
its quota to the constituent elements and tissues
of the body was really supposed to be identical
with the circulation of the blood (ततो रक्तभुगांत
बन्यवाग्यांविविधम्). This will be abundantly clear from
the following account of the course of the chyle
and the blood:—

तत: हारकुश्याक्ष्यार्क्ष्यादी भागी भवत:। खून: सुखः...
तत: सुखोऽभाग: प्रायःपुणया प्रौढःतो प्रसन्नामानः
इव विष्णुस्तुते रक्तः। अतः रक्तः यां वातं तौ of the
तत: रक्तभुगांत बन्यवाग्यां एव लिङ्गविनो भवति।
तत: प्रजान: रक्तभुगांत बन्यवाग्यां एव लिङ्गविनो। .......
तत: हारकुश्याक्ष्यार्क्ष्यादी भागी भवत:। खून: सुखः।
खूबा भागो रक्तभुगांत बन्यवाग्यां एव प्रौढःतो।
वातनेतो रक्तोऽगुण: प्रसन्नामानः प्रौढःतो भवितानि:।
This finer essence of chyle which nourishes the flesh must also be carried in the blood, on the 'irrigation channel' hypothesis (वेदार्थसङ्ग्राम). (For diagrams of the central circulation and the sympathethico-spinal nervous system, vide Appendix. The mechanism of life and the inheritance of specific and other congenital characters are also dealt with in the Appendix.)

Formation of molecular qualities in chemical compounds:—The Charaka school, which, we have seen, was an offshoot of the Sāṅkhya (cf. Charaka, Vimanasthāna, Chap. 8, यथा वातिष: घण्नाय: तथा वातस्वप्नः प्रति-संक्षासतिः) supplemented the above account of inorganic and organic compounds with a characteristically Sāṅkhya explanation of the formation of molecular qualities by chemical combination. In Charaka's view, the colours, tastes, etc. of the molecules of chemical compounds result from the collocation in unequal proportion and unstable equilibrium of the different forces latent in the atoms (Paramāṇus) themselves, द्रव्याधिकारं दधानं नृत्स्तिलिङ्गं निर्माणं नान्धनम् वातिष: मध्या-Charaka.)
Chemistry of colours.—As an interesting example of the way in which a follower of Charaka would account for the colours of chemical compounds, I may note the explanation given by the late Gangādhara Kavirāja Kaviratna in the Jalpakalpata, a commentary on the Charaka-Samhitā, published at Calcutta in 1869, premising that the Kavirāja's view is pure and genuine Charaka doctrine. Gangādhara begins with a simple statement. The qualities of the atom, he writes, tend to produce similar qualities in the molecule. A molecular quality is therefore the result of the conjunction or opposition, as the case may be, of the atomic tendencies. When, for example, the five Bhūtas combine to produce an organic compound (the human body), Tejas, Ap and Earth tend to produce red, white and black respectively, but in the body (compound substance) the yellow colour may happen to be produced as the result of these tendencies in that particular proportion and collocation. The point to note here is that the molecule forms a fresh collocation, redistributes the Mass and Energy, and sets up new forces in the system which coming into play modify the potencies (or tendencies) in the component atoms, and thus determine the resultant. This is elaborated into a curious but complete theory of the colours of chemical compounds.
The colours (and other qualities) of a simple substance (an isomeric mode of any Bhūta) are the result of the potencies lodged in that particular collocation of Mass, Energy and Essence. Now when two such substances unite, their colours etc. tend to be produced, but the combination brings on a fresh distribution of Energy, Mass and Essence, and the forces thus set free may powerfully modify or even extinguish the separate tendencies or potencies of the component simple substances. For example, when we prepare a collyrium by mixing equal parts of sulphur and mercury (the black sulphide of mercury) we find the resulting compound black. To explain this, it has to be remembered that each of the substances (sulphur and mercury) contains Sattva (Essence), Rajas (Energy) and Tamas (Mass) in different proportions, and that predominant Tamas (Inertia, Mass) always produces black, predominant Sattva (Essence) white, and predominant Rajas (Energy) red. Now in the black sulphide of mercury, the white of the mercury tends to produce white, and the yellow of the sulphur yellow; and if these tendencies were not obstructed, the result would be a mixed colour. But, in the particular collocation in question, the Tamas of the mercury becomes intensive (विपक्ष), and the black of the now intensive Tamas
extinguishes the white in the uncompounded mercury, which was due to prevailing Sattva, as well as the yellow of the uncompounded sulphur, which was due to the combined operation of white-producing Sattva and red-producing Rajas. Again, when, with proper apparatus and by the application of heat, we combine mercury and sulphur to produce the red sulphide of mercury, the resulting colour is explained by the fact that in this new collocation the Rajas (Energy)—probably of the mercury, though Gaṅgaḍhara does not specify—becomes intensive (वीर्य), and extinguishing both the white-producing Sattva of the mercury and the yellow-producing Sattva-Rajas of the sulphur, imparts a red colour to the compound. In these cases, as also in the formation of red by mixing powdered turmeric with lime, i.e., whenever a new colour is produced in the compound, it is to be explained by the dominance of Tamas, Rajas or Sattva, or their combinations, and the extinction of the uncompounded tendencies (or potencies) by the forces set free in the new collocation. But there are other cases where the colour of the compound is a mixed colour resulting from the colours of the combining substances, e.g., when sulphide of mercury and calcined tin are mixed, the resulting colour is evidently a mixed one (Pātala, pink), which is
easily explained by the colours of the component elements (the red of the sulphide of mercury and the white of the calcined tin). In the same way, in a mechanical aggregate, as in a piece of cloth, the colour is white, where the threads are white.
Parináma-váda versus Krambha-váda: Charaka’s view of the formation of a new quality or a new substance is based on the Sánkhya teaching as to the conservation and transformation of Energy, and brings chemical synthesis in a line with evolutionary change (परिशाल.). On this view, a new substance may arise by spontaneous or isomeric change, i.e., by the inter-play of Energies within the system of any given substance, in the absence of any action from without. New qualities like new substances are only readjustments of the old, and continual changes are going on by spontaneous disintegration and recombination. Opposed to this evolutionary view of chemical synthesis is the Nyáya-Vaiseshika doctrine of Krambha-váda, according to which no change of substance or quality, no effect, in short, can take
place except by the action of one component element (substance or quality) on another. A binary molecule, for example, cannot possess any ‘specific quality’ (विशेषता) of a kind not represented in each of the two component atoms. In the cosmic process, no atom can exist free and uncombined with another atom, and every ‘specific quality’ in a substance can be ultimately analysed into the union of two ‘specific qualities’ of the same class in two ultimate particles which cannot be further divided. A single colour, smell or taste in a single particle, until it can link itself on to another specific quality of its own class in a second particle, cannot characterise any substance formed by the union of these particles as material causes. Hence an Earth-atom cannot unite with an Ap-atom, to form a new substance of which both the particles must be equally regarded as material causes. At any rate, such a compound, if effected, would be smell-less, as of the two constituent atoms, only one, viz., the Earth-atom, possesses smell. A compound of Earth and Váyu would be smell-less, colourless and tasteless, and so on. The Nyáya-Vaiseshika does not deny that there may be compounds of different Bhūtas, nor does it deny the causal operation of specific qualities as efficient or energising (dynamic) causes (कारक, शक्ति), but it refuses to place
these compounds on the same footing as compounds of isomeric modes of the same Bhúta; and it accepts the 'material' causality, in such cases of only one of the Bhútas, regarding the others as co-efficients' (फमितकार्य).

The earlier Sáṅkhyaṇas including the medical schools of ancient India brushed all this aside as a distinction without a difference. The Vedantists, as we shall presently see, flouted this doctrine of Aśrambhā-váda. The Jainas, in opposing this Vaisesika view of atomic combination, hit upon a solution of the problem of chemical affinity. Others again, found out a via media. They held, as we learn from the reports of Udyotakara in the Nyāya-vártika, and of Váchaspati Misra in the Tátparyyátiká, that a molecule of the structure EA (one atom of Earth and one of Ap) would exhibit some variety of colour and taste resulting from the joint action of the atoms and of their several colours and tastes. But as in the combination EA only the Earth-atom possesses smell, and the Ap-atom is smell-less, and as moreover no quality in a compound substance can result except from the joint action of the similar (potential) qualities of at least two component elements, it follows that a molecule of the structure EA would not manifest the energy of smell potentially contained in the Earth-atom.
Hence, admitting the combination EA for a smell-less compound, the upholders of this view would suppose a molecule of the type $E_A$ (i.e., two atoms of Earth and one of Ap) to explain any bi-Bhautic compound of Earth and Ap (like the plant saps and fruit juices) which exhibits smell in addition to the peculiarities of colour and taste. (Cf. Vāchaspati’s comment on Udyotakara’s refutation of this view:—

मय地位ः। दत्तिके दार्शनिकत्वतः दर्शनं दृढं तत्त्वसुन्दरं प्रसिद्धंत:। यदी दद्धिद्वाकु संवेदकर्मन्तर विज्ञानं एवावेत ज्ञानं
रश्मिकत्वात् प्रविष्ट विद्विवर्णौऽस्य एवकं विद्विवर्णरिपु:।
दत्त वर्ण दार्शनिकसंवेदं ज्ञानस्वरूपसंवेदं दर्शाण्यु:। पर
भाष्यवाजनं दक्ष्यां दार्शनिकत्वात्। भगवान् एव: परभाष्यवाजनं ग
भाष्याय भाष्य:।)

Measures of Time and Space. Size of atoms.

The Siddhānta-Siromani gives the following measures of Time:

30 Kshanas (क्षण) = 1 day, 2 Ghatikās = 1 Kshana,
30 Kalas = 1 Ghatikā, 30 Kāshthās = 1 Kalā,
18 Nimeshas = 1 Kāshthā, 30 Tatparas
1 Nimesha, and 100 Trutis = 1 Tatpara.

This makes a Truti of time equal to 1 32 of a second, which is nearly the measure of
the Paramāṇu of time, as given in the Vishnu-
parāṇa (vide Bhāskara's Siddhānta-Sīromani—
कालवाणी)-

The above measures were in use among the
astronomers, but the physicists computed according
to the following table given both in Udayana's
Kiranāvali and Śrīdhara's Nyāyakandali:—30
Muhūrtas = 1 day (24 hours), 30 Kalās = 1 Mu-
hūrta, 30 Kāshṭhas = 1 Kalā, 18 Nimeshas = 1
Kāshṭha, 2 Lavas = 1 Nimesha, 2 Kshanas = 1 Lava.

This makes 1 Kshana of the Nyāya-Vaiśeshika
equal to \( \frac{1}{27} \) of a second. The Nyāya assumes
that the unit of physical change (or the time
occupied by any single antecedent step in a causal
series before the succeeding step is ushered in)
is equal to a Kshana (or \( \frac{1}{27} \) of a second). The
astronomers were familiar with far smaller mea-

sures of time. The astronomical Truti of time
measures about the thirty-four-thousandth part
of a second. This is of special value in deter-

mining the exact character of Bhāskara's claim
to be regarded as the precursor of Newton in the
discovery of the principle of the Differential Cal-
culus, as well as in its application to astronomical problems and computations. This claim, as I proceed to show, is absolutely established; it is indeed far stronger than Archimedes's to the conception of a rudimentary process of Integration. Bhaskara in computing the "instantaneous motion" (तात्त्वावधिवर्ग) of a planet compares its successive positions, and regards its motion as constant during the interval (which of course cannot be greater than a Truti of time, though it may be indefinitely less). This tātkālika motion is no other than the differentia of the planet’s longitude, and Bāpudeva Sāstrī claims that both the conception of the instantaneous motion and the method of determining it plainly show that Bhaskara was acquainted with the principle of the Differential Calculus. On the data before him, Mr. Spottiswoode remarks that Bāpudeva Sāstrī "overstates the case." Bhaskara "makes no allusion to one of the most essential features of the Differential Calculus, viz. the infinitesimal magnitude of the intervals of time and space therein employed. Nor indeed is anything specifically said about the fact that the method is an approximate one."

"With all these reservations" Mr. Spottiswoode continues, "it must be admitted that the formula he establishes and the method of establishing it
bear a strong analogy to the corresponding process in modern mathematical astronomy" (viz., the determination of the differential of the planet’s longitude,—by no means the first step in transcendental analysis or in its application to astronomy). And Mr. Spottiswoode concludes by stating that mathematicians in Europe will be surprised to learn of the existence of such a process in the age of Bhāskara (circa 1150 A.D. —born 1114 A.D.) Mr. Spottiswoode’s second objection that Bhāskara does not specifically state that the method of the Calculus is only approximative cannot be taken seriously. The conception of limit and the computation of errors came late in the history of the Calculuses of Fluxions and Infinitesimals. For the rest, Bhāskara introduces his computation expressly as a "correction" of Brahma-gupta’s rough simplification. The first objection (viz., that Bhāskara makes no allusion to the infinitesimal magnitude of the intervals of space and time employed) would be more to the point, if it were well founded. But it is not, and Mr. Spottiswoode’s error was due to the insufficiency of the data supplied to him. As a matter of fact, even Bhāskara’s unit, the Truti of time (or Paramānu), is exceedingly small as the very name implies, being about one thirty-four-thousandth of a second of time. And in the passage in which Bhāskara describes the process, he distinguishes
between Sthúla-gati and Súkshma-gati (velocity roughly measured, and measured accurately *i.e.*, by reference to indefinitely small quantities, for Súkshma, as we have seen, has always a reference to the Anu, the indefinitely small). Indeed he expressly mentions that the Sthúla-gati takes only Sthúla-kāla (finite time) into consideration, and that the determination of the Tátkálikí Gati (Súkshma-gati) must have reference to the moment (*vidyākāra*), which is an indefinitely small quantity of time being of course smaller than his unit, the Truti. (Cf. दूसरे निष्ठुरात्मक गतिः कथा दृष्टी मात्राकी चयनः......तदा व्यापकबल्लिष्ठतात्मक गतिः तत्त्वाकारपूर्वकः गतिः सत्प्रभावणम् वादुः पुज्यते। तथा व्याकृतफांकः । तदा दूस्रतरक्षितः दूसरासंगता वा जन्मसंगता आदिवा खूचबा वाः उज्ज्वले खूचवाभादः। तत्क्षणा गति: महस्तात्म प्रतिच्छयं अन्यं न भवति अवस्तयते अये विचारात्मकः;—nothing can be clearer than this conception of 'momentary' motion.—Bháskara, Siddhánta-Síromani, Ganitádhyaśa, Gatisphutiparakarana: cf. also प्रक्षेपणं तथा न अथा सफळः, *ibid.*, cf. also Goládhyaśa, Tátkálikí-karana-vásana-prakarana, where Bháskara points out that the mode of computing adopted by the A'cháryya (Brahmagupta) is a rough simplification. The computation of relative motion and the idea of resolved components of motion were of course familiar to
the astronomers.—(Cf. एवं साधारणः साधारणं दक्षिणम् चतुर्थिनो नामिता च चच्चं विषिष्ठः i. i. ibid.) I may add en passant that Bhāskara’s formula for the computation of a table of Sines also implies his use of the principle of the Differential Calculus.

Measures of weight and capacity. The Amarakosha mentions measures of three kinds—weight, length and capacity (जाने सुवार्ण स्वरूपः).

The Krishnala (Guṇjā, Raktikā, the black and red berry of the Shrub Abrus Precatorius) was employed as a natural measure of weight. 80 Krishnala berries on the average weigh 105 grains Troy, and this must be taken as the basis of our computation, though in current practice 80 Krishnalas are taken to be equivalent to 210 grains. One Krishnala was supposed to weigh as much as 3 medium-sized barley seeds (मध्य चण), one of the latter as much as 6 white mustard seeds (गोरखचं), one white mustard as much as 3 Rāji mustard seeds (राजी सरसं), one of these seeds as much as 3 Likshas, and one Liksha as much as 8 Rajas or Trasarenu.

We now come to conventional measures. One gold Máshá was the weight of 5 Krishnalas of gold, 1 Suvarna or Tolá weighed as much as 16 Máshás, and one Pala as much as 4 Suvarnas or Tolás. A Pala of gold therefore weighs 320 Krishnalas (Manu, Chap. VIII, Vishnu, Chap. IV, and Yājñavalkya, Chap. I).
A Máshá of gold therefore would weigh $\frac{6}{16}$ grains; a Tolá, 105 grains, (in current practice it weighs nearly double as I have stated); and a Pala, 420 grains Troy.

The measures for silver were the following:—

1 Silver Máshá = 2 Krishnalas, 1 Dharana = 16 Silver Máshás, and 1 Pala = 10 Dharanas. A Pala of silver would therefore weigh 320 Krishnalas. In other words, the Pala was a fixed measure of weight, and was equal to about 420 grains Troy, or double this, if we take the Krishnala of current practice.

A Pala, which equals 320 Krishnalas, was subdivided by 4, 16 and 5 successively for gold, and by 10, 16 and 2 successively for silver. A Suvarna (or Tolá) of gold corresponds roughly to a Dharana of silver, and a gold Máshá to a silver Máshá, but the sizes (or volumes) are not the same, and we must not therefore conclude that gold was supposed to be heavier than silver in the proportion of 5 to 2.

We find that 1296 Trasarenu equal 1 Krishnala. A Trasarenu, as a measure of weight, therefore, is the equivalent of $\frac{1}{144}$ of a grain Troy, or double this according to current measures.

But the Trasarenu of physics is a different conception. It stands for the minimum visible, i.e., as the physicists define it, that which is just discernible as a glancing particle in the slan-
ting beams of the morning (or afternoon) sun, coming into a dark room through a chink or orifice of a window. This is a measure of size (or rather stimulus limen).

Measures of Capacity. Here the standard was furnished by the Kudava (कुदवा), a vessel described as 3 Āṅgulis long, 3 Āṅgulis broad, and 1½ Āṅguli deep,—with a cubical capacity of 13½ cubical Āṅgulis. 4 Kudavas = 1 Prastha. 4 Prasthas = 1 Āḍhaka, 4 Āḍhakas = 1 Dronas and 4 Dronas = 1 Khāri or Bhāra.

24 Āṅgulis make 1 Hasta, cubit, which may be taken to be 18 or 19 inches. A Kudava was divided into 4 Palas, and there can be no doubt that originally water of the weight of 4 Palas was found to be actually contained in a vessel of the cubical capacity of a Kudava. If we take the ancient cubit to have been 19 inches, the Kudava would contain nearly 4 Palas of distilled water at 30° Centigrade. On a cubit of 18 inches, the Kudava would contain about 3½ Palas.

The Kudava in current medical practice is supposed to represent a cubical vessel, each side being 4 Āṅgulis. This would give a capacity of 27 cubic inches, if we take the modern cubit of 18 inches. The Kavirājas take a Kudava to contain 8 Palas of water, and as 1 Pala = 320 Krishnalas, and 80 Krishnalas are now taken to be equal to 210 grains Troy, a vessel of a capacity
of 27 cubic inches is accordingly supposed to contain about 6720 grains Troy,—which is not very wide of the mark, being about 1.3 per cent. short for distilled water at 62 Fahrenheit.

Size of the minimum visible; size of an atom.

The supposed thickness of the just discernible mote in the sunbeam called a Paramanu in Technology, Silpa-sāstra, (and a Trasarenu in Natural Philosophy) follows directly from Varāhamihira’s table:—8 Paramánus make 1 Rajas (or Ratharenu,—cp. the Manasara), 8 Rajas make 1 Válágra (filament of hair), 8 Válágras make 1 Likshá, 8 Likshás make 1 Yúká, 8 Yúkás make 1 Yava, 8 Yavas (the Manasara has 4) make 1 Anguli (superior), 24 Angulis make 1 Hasta (cubit, esser cubit, 18 inches). The thickness of the minimum visible (the finest perceptible mote in the slanting sunbeam) is therefore taken to be 3.2" or \( \frac{3}{4} \) of an inch. The volume of a spherical Trasarenu (or Paramánu of the Silpa-sastra) would therefore be \( \frac{4}{3} \pi \frac{3}{4} \) of a cubic inch. It may be here noted that such a Trasarenu is supposed in the medical schools to contain 30 chemical atoms (Paramanus of Natural Philosophy) according to one estimate, or 60 according to another. The size of an atom must then have been conceived to be less than \( \pi 3.5 \) of a cubic inch.

यत्राद्वा द्रोहवाकारपितामहेन्द्रियां यजोःकुं न फ्लेमिटि बाहुधुरानि बजोकुर्वे पत्त्र बलिया भयावति संहाया—Varāhamihira, Vṛhatsambhitā, Chap. 57, Sūkta 2—अणान्यर्गते
The magnitude of a Paramānu is called Pārimādvalya (पारिमाध्यल्य) in the Nyāya-Vaiseshika, the name suggesting that the Paramānus were conceived to be spherical in shape. The Nyāya-Vaiseshika calls a Paramānu a mere point without any dimensions, but in the Sāṅkhya-Pātañjala, a Paramānu, though indefinitely small, had still dimensions, being divisible into Tanmātras, which were themselves integrations of Bhūtādi. The diameter of a spherical Paramānu must have been conceived to be less than \(3.2^{30}\) of an inch (i.e. less than the conventional Paramānu with which linear measures begin), and the volume of a Paramānu would therefore, in accordance with Bhāskara’s formula, be smaller than \(\frac{1}{4} \pi 3^3.2^{41}\) or \(\pi 3^2.2^{41}\) of a cubic inch where \(\pi = \frac{41}{2} \frac{3}{8}\). The Tanmātras were conceived as smaller still.

That these were conventional measures arbitrarily assumed goes without question, for, of course, the Hindus had no physical data for a mathematical calculation of these minute quantities. A Vālágra (hair-tip, or finest filament of hair), for example, is taken to be \(3.2^{-14}\) of an inch thick; i.e. less than one five-thousandth fraction.
of an inch in thickness; and a fibril of the networks of Dhamani or Nadi (nerve) that supply the pores of the skin (papillae? सुखानि रेक्षकुप विवरणि, Susruta) was supposed to be about a thousandth part of the finest hair in thickness, or युक्त of the ‘minimum visible,’ and therefore about $3 \times 10^{-12}$ of an inch thick (cf. सिसावनामोदप्रत्यार्थः रूपः सिसावागणिसिसावास प्रत्यार्थि, Pañchadasí), but it is evident that these measures were arbitrarily fixed upon, instead of being arrived at by calculation or actual measurement. Indeed, Charaka expressly states that the number of Śīrás and Dhamanis in the body (three million fifty-six thousand and nine hundred) is only a conjectural estimate (अनिन्द्यक्षमः परं तत्तंगि—Sārīrasthāna, Chap. VII).

My account of the chemistry of the Sāṅkhya-Pātañjala, and of the affiliated Yoga and medical schools, has anticipated in several points the views of the Vedānta and the Nyāya-Vaiseshika. The chemical facts, processes and apparatus are indeed common to all the schools. In the following account of the chemistry of the schools other than the Sāṅkhya-Pātañjala, I will confine myself to the theory of the subject, and even of this I will attempt only the briefest outline.

The Vedāntic view:—
The Vedāntists believe Māyā to be the ‘material cause’ (समाधाबारक) of the world. The power
of Máyá is the power to realise the unreal—to impart practical Reality or mediate existence to that which does not and cannot possess absolute Reality or self-existence. Máyá is at once real and unreal, while the Brahma (Self) is absolute Reality, absolute Intelligence and absolute Bliss. The world evolves out of Máyá (मायापरिषाप), so that Máyá in the Vedánta replaces the Prakriti of the Sánkhya. But Máyá, and by implication the world, originate out of Brahma, not by a process of evolution (परिषाप), but of Vivarta (self-alienation). The self-alienation of the Absolute, acting through Máyá, produces in the beginning A’kása, one, infinite, ubiquitous, imponderable, inert and all-pervasive. The world thus begun goes on evolving, in increasing complexity. The other Súkshma Bhútas, classes of subtile matter, evolve from A’kása, in an ascending linear order,—A’kása giving off Váyu, Váyu giving off Tejas, Tejas giving off Ap, and Ap giving off Earth. A’kása, one, infinite, all-pervasive, has the capacity of sound. Váyu, subtile gaseous matter, emanates from the universal A’kása, and is instinct with the potential of mechanical energy (impact, pressure). (चरण, प्रकारकल्प, रस्सन, अूर्त, —वायुस्व चेतात्तेतेन संवृविनाधूतत्वान—Vidvanmanorāñjiní). Tejas, subtile radiant matter, emanates from Váyu, and contains in potentia the energy of light and heat. Ap, subtile viscous matter, is the
transformation of Tejas, and is instinct with
the energy that stimulates the nerve of taste, and
lastly, Earth, subtile hard matter, which is the
transformation of Ap, possesses the latent energy
of smell.

But the subtile rudiments of matter must be
compounded in various ways, to give rise to the
gross constituent matter of the world. These forms
of gross matter are called Mahábhútas. There
are five kinds of Mahábhúta (gross matter corre-
sponding to the five Súkshma Bhútas (subtile ma-
tter, and the process by which a Mahábhúta is pro-
duced from the Súkshma Bhútas is called Pañchí-
karaṇa (quintuplication). All the five Súkshma
Bhútas are present as ingredients, though in
different proportions, in each Mahábhúta.

The Mahábhúta Earth, gross earth-matter, is
composed of four parts of subtile earth-matter,
and one part each of the other forms of subtile
matter. The Mahábhúta Váyu is composed of
four parts of subtile gaseous matter and one
part each of the other forms of subtile matter.
And similarly with other Mahábhútas.

Hence if ak, v, t, ap, e, represent the five forms
of subtile matter (A'kára, Váyu, Tejas, Ap and
Earth), and AK, V, T, AP, E, stand for the cor-
responding Mahábhútas, we may represent the con-
stitution of the Mahábhútas as follows:—
AK = ak₄ (v₁, t₁, ap₁, e₁), ak₄ being the radicle.
V = v₄ (ak₁, t₁, ap₁, e₁), v₄ being the radicle.
T = t₄ (ak₁, v₁, ap₁, e₁), t₄ being the radicle.
AP = ap₄ (ak₁, v₁, t₁, e₁), ap₄ being the radicle.
E = e₄ (ak₁, v₁, t₁, ap₁), e₄ being the radicle.

In forms of gross or compounded matter, the potential energies (or qualities) become actualised. The Mahābhūta Aṅkāsa manifests sound; Vāyu, sound and mechanical energy; Tejas, sound, mechanical energy and heat-light; Ap, the energy of the taste-stimulus in addition; and finally Earth, the energy of the smell-stimulus added to the foregoing.

The Pañchadasi characterises the different Mahābhūtas by their typical sounds; e.g., Aṅkāsa by the echo (hollow booming sound); Vāyu (air) by a sibilant sound, hissing, susurration (imitative symbol, Visi); Tejas (fire) by a puffing (or roaring) sound (imitative symbol, Bhugubhugu); Ap (water) by a liquid sound (imitative symbol Culu-Culu, gurgle, splash-plash, glut-glut); and finally Earth by a splitting or rattling sound, a crack or a thud (symbol, kad-kada).—Chap. II. Bhūtaviveka, Sūloka 3, Pañchadasi)

Others hold that Aṅkāsa, Ether, never enters as a component part, and is always one and indivisible. In this view, the four Mahābhūtas—Vāyu, Tejas, Ap and Earth alone are supposed to be com-
pounded, and by a process which may be called quaternion (cf. the Neo-Platonist quaternion):

\[ V = v_i (t_i \cdot a_p \cdot e_1) \]

\[ T = t_i (v_i \cdot a_p \cdot e_1) \]

\[ AP = a_{p_i} (v_i \cdot t_i \cdot e_1) \]

\[ E = e_1 (v_1 \cdot t_1 \cdot a_p) \]

These compound forms, as before, are supposed to exercise their specific energies actively. Others again hold that the Mahábhútas—Tejas, Ap and Earth alone are compounded by a process named Trivrit-karana (triplication). Thus \( T = t_i (a_p \cdot e_1) \), \( AP = a_{p_i} (t_i \cdot e_1) \), \( E = e_1 (t_1 \cdot a_p) \).

The Súkshma-bhútas are forms of homogeneous and continuous matter, without any atomicity of structure; the Mahábhútas are composite; but even these are regarded as continuous, and without any atomic structure. The Vedánta speaks of Ánu (Paramánu) not as an ultimate indivisible discrete constituent of matter, but as the smallest conceivable quantum or measure of matter. In the Sánkhya doctrine, the atomic structure is ordinarily accepted. The Gunas are supposed to be परिमित and अच्छु bounded and indefinitely small in size (except the Gunas giving rise to Ákáśa and Manas which are unlimited अपरिमित); and hence the Tanmátras and Paramánus must be conceived to have a discrete structure.

As I have already noted in my account of the genesis of Tanmátras and Paramánus, various
schools of Vedántists (e.g. the Rámanujists and the followers of Nimbárka) combined, in the orthodox fashion of the Smrītis and the Purāṇas, the Vedántic theosophy with the Sāṅkhya cosmology especially as regards Prakṛiti and the order of creation and dissolution. For example, the Vedánta kaustubhaprabhá, fortifying itself with texts from the Vishnu Purāṇa and the Subala and Gopála Upanishads, contends that, at the cosmic dissolution (Pralaya), each Mahábhúta merges into the one that preceded it in the order of creation by first disintegrating into its own proper Tanmátric form (तन्मात्रारूप), and that the Mahábhúta Ākāsa merges into the original Tanmátras, which then lapse into Bhútádi, the supersubtle rudiment matter, proto-matter (Chap II, Pada 3, Sútra 14).

Parináma—Evolutionary Process:—When the Mahábhútas are once formed, the different kinds of substance are derived from them by the evolutionary process called Parináma (परिनामः, transformation). Matter is constantly undergoing change of state. The effect is only the cause in a new collocation (विविधमानसंयोगं भावम्). Change is of two kinds:—

(1) Change by a spontaneous process, without external influence, including isomeric change (सामार्थविषय परिवर्तन). The Vedántists believe in
spontaneous disintegration and reintegration. Action from without, impressed force \textit{ab extra}, is not, \textit{pace} the Naiyāyikas, always a condition of change of state (whether of rest or of motion);—nor is it necessary that more than one substance should combine to generate another substance or variety of substance (e.g. the formation of curds from milk, of ice from water \textit{etc.}) All this is directed against the Nyāya doctrine (\textit{Atreaghavāda}).

(2) Change due to combination with other substances (\textit{dvānamārgavāgen}). Such combination may produce (1) a compound substance possessing like qualities with the constituents (\textit{samānāyakavāyatarpāna}), or (2) unlike compounds with new qualities, "heteropathic effects" (\textit{vibhāyakāyopāya}). Any new quality thus evolved through (chemical) combination is called \textit{Samhata-bhūta-dharma} (\textit{samśayaḥ}). e.g. the intoxicating power of the fermented rice and molasses, which does not exist in the ingredients taken separately. (\textit{madhayakriyā prabhavābhiniveśaṃ abhinivesaṃ medhāya bhurāenā bhurāḥ}). This \textit{Sambhūyakriyā} (\textit{sambhūyakriya}, \textit{bhurā}) corresponds to chemical combination, and the Vedāntists, like the Śāṅkhyas, explain this only as the evolution of the latent energy (\textit{prākāya, prākāyopāya}) in a new collocation (\textit{medhāya, prabhavābhiniveśa}). But, unlike the mediæval
Sāṅkhya, the Vedānta freely recognises the combination of heterogeneous Bhūtas. Thus, Earth, Ap, Tejas and Vāyu freely combine in different proportions and groupings to produce the variety of substances in the world. For example, the animal organism is a compound of all the five Bhūtas (पाथ भौतिक). It is not merely the concomitant or efficient causes that may be heterogeneous to the material cause, as the Naiyāyikas contend, but several heterogeneous substances (or Bhūtas) may unite as 'material causes' to produce a new substance.

The Vedāntists resolve all activity, physical, vital as well as psychical, into modes of motion, subtile cosmic motion (परिखल, सब्ज़ेःपरि खल्द—Saṅkara; वा खर: परिखल्पालक्यादत, प्रात्स परिखल्पालक्यादत्त—वर्द्ध अं खल्द खल्दण्य च तहड़ भन:सांन्दलाप्रः—Saṅkara); but they give a separate substantive existence to the agents, the vital principle (प्रात्स) and the mind (बनः), though these are also evolutionary transformations of the Sūkṣma Bhūtas (forms of subtile matter). What is common to the Nyāya, the Vedānta and the Sāṅkhya is that Consciousness or Intelligence (सत्स) transcends Matter; but the Naiyāyikas as pluralists hold that vital and psychical activities are also immaterial and cannot be resolved into motion (परिखल्द);—the Vedāntists resolve these activities into subtile motion, but
ascibe them to a substantive quasi-material Life Principle and Mind, the all-mirroring Intelligence (चेतना) alone being immaterial and transcendent: and the Sāṅkhyas accept the substantive existence of the Mind Principle (चेतन:) as derived co-ordinately with the Sūkshma Bhūtas or Tanmātras from individualised Prakṛiti (Ahaṅkāra), but resolve Life into a mere resultant activity of the bodily organs, viz., the organs of sense and movement, and the psychic principle (चेतन:).

पञ्जीकृतः — द्विधा विभाव प्रेमिक पत्तिरं प्रयत्नं युजः।
सहस्रपद्रिविश्वेष्यायंबैकणातु पञ्च पञ्च तेः।

वधा शरणेनातृतो क्षतां चूतां च रुदरसरब्रवहारानाम
रूपते कारणोपायतम्। "विभावकर्त्य" चूतं सदृशं धृतप्रवहकर्त्य
अति हिंसा। तद्वज्ञानी पञ्जीकृतम्। नारं चाकायम् गंधोरेभिः
सुंदरते सफुद्रवर्ति सर्वदा वेषजीयं (विद्न्यानोर्जङ्जिनी) — चासि
स्त्रियः परीरे संवेदिकाम्प चूतां चाकायम्प्रगतिः। अववायभूतः
वन्नक्षेदनकाठिन्यानं सर्वोत्तरेनुभवसिद्धातत्। चक्षुस्तुञ्जारोपणमा
पञ्ज्ञातं चूतां च जनन देशे जनोंसिन द्विते नन्दत्योरिंथ चक्षु
वशवायवल्लेव पञ्चपुर्तर्द्वोपयुक्तं। न च हा पूर्वस्तु एक
द्वाबानां च चाकायम्प चारवधत्वानुपत्तिरिति वाच्यं।
चारवधत्यां च च चाकायम्प चारवधत्वानुपत्तिरिति वाच्यं।
एकाधापि दुर्गाधारवाच्य: च धारा-र्जतवधारवाच्य: च।
बलस्वर्ग पञ्च्यानं चूतां च चारवधत्वानुपत्तिरिति निराकारत्वान। च।
सब्जातं सिद्धं
परीरे साधनाजीविविवित्रति। Vidvanmanoñjinī.
The atomic theory of the Buddhists: --The Vaibhāshikas and the Sautrāntikas hold that the Vāyu-atoms are touch-sensibles, having impact or pressure for their characteristic property, and by aggregation form the element Vāyu; the Tejas-atoms are colour-and-touch-sensibles, having heat for their characteristic, and by aggregation form the Tejas Bhūta; the Ap-atoms are taste-colour-and-touch-sensibles with a characteristic viscosity, and form the Ap-element by aggregation; and finally the Earth-atoms are smell-taste-colour-and-touch-sensibles possessing a characteristic dryness or roughness (खर्च), and by their aggregation form the Earth-element. The Bhūtas
thus originated combine to form aggregates, which are classed as inorganic substances, organisms and organs. (काशेरग्रीवस्वरः) — Udyotakara's extract from the Buddhist Sūtras, Nyāya Vārtika. Chap. I. Aññika 1, Sūtra 14. cf. Vāchaspati's fuller extract —

also the Buddhist commentary — काशे कामघाती चक्र-द्रव्यक: अयुः। कुपरसगमस्सर्गोऽर्जुन चतुरि द्रव्यार्य शुचिव्यपण- 
तेजोवासः राज्य चतुरि — Vāchaspati, Tātparyyatikā, loc.cit. — also चर्चा होरोश्यामभायान भूतानि—ride Udyo-

the Jainas: — Of the nine categories of the Jainas, that of Ajīva (the not-soul or non-Ego) consists of five entities, four of which are immaterial (अशूर्य), viz., merit, demerit, space and Time, and the fifth, material (शून्य, possessing figure). The last is called Pudgala (matter), and this alone is the vehicle of Energy, which is essentially kinetic, i.e. of the nature of motion. Everything in the world of not-soul (the non-Ego) is either an entity (धीर), or a change of state in an entity (चक्राव). Pudgala (matter) and its changes of state (परिवर्त), whether of the nature of subtle motion (परिस्थित) or of Evolution (परिवार्त), must furnish the physical as opposed to the metaphysical basis of all our explanations of Nature. Pud-
gala (Matter) exists in two forms,—Anu (atom) and Skandha (aggregate). The Jainas begin with an absolutely homogeneous mass of Pudgalas, which, by differentiation (भेदः) breaks up into several kinds of atoms qualitatively determined, and by differentiation, integration, and differentiation in the integrated (संघात्, भेदःत, संतानभेदात्—Umá-srátí, Chap. V, Sútra 26), forms aggregates (Skandhas). An Anu has no parts, no beginning, middle or end. An Anu is not only infinitesimal, but also eternal and ultimate. A Skandha may vary from a binary aggregate (द्वाशु कः) to an infinitum (अनन्ताशु जः). A binary Skandha is an aggregate of two Anus (atoms), a tertiary Skandha is formed by the addition of an atom (Anu) to the binary (द्वाशु कः) and so on ad infinitum. The ascending grades are (1) what can be numbered (वंश्येव ), (2) indefinitely large (अवंश्येव ), (3) infinity of the first order (अनन्त ), (4) infinity of the second order (अनन्तागत ), and so on.

General Properties of Matter:—

The specific characters of the Pudgalas (Matter) are of two kinds, (1) those which are found in atoms as well as in aggregates, and (2) those which are found only in aggregates. Qualities of touch, taste, smell and colour come under the first head.
The original Pudgalas being homogeneous and indeterminate, all sensible qualities, including the infra-sensible qualities of atoms, are the result of evolution (परिबार्न). Every atom thus evolved possesses an infra-sensible (or potential) taste, smell and colour, (one kind of each) and two infra-sensible tactile qualities, e.g. a certain degree of roughness or smoothness (or dryness and moistness?) and of heat or cold. Earth-atoms, Ap-atoms, etc. are but differentiations of the originally homogeneous Pudgalas. The tactile qualities (खर, निर, चपा, ढील) appear first, but qualities of taste, smell and colour are involved in the possession of tactile qualities. An aggregate (Skandha), whether binary, tertiary or of a higher order, possesses (in addition to touch, taste, smell, and colour) the following physical characters:—(1) sound, (2) atomic linking, or mutual attraction and repulsion of atoms, (3) dimension, small or great, (4) figure, (5) divisibility,* (6) opacity and casting of shadows, and (7) radiant heat and light.

Sensible qualities. Tactile qualities are of the following kinds—hardness or softness, heaviness or lightness (degrees of pressure), heat or cold, and roughness or smoothness (or dryness and viscosity†). Of these, the atoms (Anus) possess only temperature, and degrees of roughness.
or smoothness, but all the four kinds of tactile qualities in different degrees and combinations characterise aggregates of matter from the binary molecule upwards. The Jainas appear to have thought that gravity was developed in molecules as the result of atomic linking. Simple tastes are of five kinds,—bitter, pungent, astringent, acid and sweet. Salt is supposed by some to be resolvable into sweet, while others consider it as a compound taste. Smells are either pleasant or unpleasant. Mallishena notes some elementary varieties of unpleasant smell, e.g. the smell of asafoetida, ordure, etc. The simple colours are five—black, blue, red, yellow and white. Sounds may be classed as loud or faint, bass (thick) or treble (hollow), clang or articulate speech.

The most remarkable contribution of the Jainas to the atomic theory relates to their analysis of atomic linking, or the mutual attraction (or repulsion) of atoms, in the formation of molecules. The question is raised in Umasvati’s Jaina Sutras (circa A.D. 40)—what constitutes atomic linking? Is mere contact (or juxtaposition) of atoms sufficient to cause linking? No distinction is here made between the forces that bind together atoms of the same Bhuta, and the chemical affinity of one Bhuta to another. The Jainas hold that the different classes of elementary substances (Bhutas) are all evolved from the same primordial atoms.
यथा: खामाथु। च्या च। वारूणवेश तदनां खुच्चो गिलख। भवति परमाणुः। यथरस्वरमृच्छी दिक्षर्येः काके विक्रृय।
तत्त्वारूपोऽसः खामाथुः गहा एव। खामाथुवत संधात्वेदेश्वरत्य-चतुष्पदाने। संधात्तीते दात वासवेद्वार्त्तिः। द्वयोऽ परमाणूः संधाताकोऽवर्धेषः। द्विमेदेशलायोऽसः संधातात दिक्षर्येः। एवं स्वस्वाध्वानस्वस्ववाच्याबाह्यगतानां अनन्तानन्तानां च प्रदेशानां संधातात प्रदेशः। भेदार्थः। भेदार्थ वराव्युज्ज्वलयति न संधातात्वादिति। अबा१। किं संधोगमाहायेष संधातात भवति।
खामाथुः विद्विद्विल्लित काके विद्विल्लित रूपः। अबोल्यते। वति संबोधे बद्यन संधाते भवतोति। खिस्मणतावादः। न अवस्था-युक्तानां। खिस्मणतायः। युक्तायः। वति संबोधे बद्यन संधाते भवतोति। खिस्मणतावादः। अद्य तत्त्वायः।
किमस्य महासये महासयेष भवतोति। अद्य तत्त्वायः। किमस्य महासये महासयेष भवतोति। अद्य तत्त्वायः।
अद्य तत्त्वायः। अद्य तत्त्वायः। अद्य तत्त्वायः। अद्य तत्त्वायः। अद्य तत्त्वायः। अद्य तत्त्वायः।
The Nyáya-Vaiseshika chemical theory: a brief summary.

I must content myself here with a brief and rapid sketch of the chemistry of the Nyáya Vaiseshika, which I shall elaborate in connection with the mechanics and physics of the ancient Hindus in a separate paper.

The relation of the specific characters of molecules (and higher aggregates) to the original atomic qualities is reduced in the Nyáya-Vaiseshika to the following canons:—

(a) कार्यम्युस्म् कारक्यमुस्म्-पूर्वब्रजम्।

(b) समानज्ञातीयब्रजं संग्रह: दृष्टार्थक: न विशालीयसंबंधां।

(Here दृष्ट is used in a narrow technical sense, so as to exclude the quasi-compound substances). (c) अपाक्राक्षकपरसङ्गमभूतं परिमार्यैः कल्वै कारक्य-मुस्म्खल-विश्वस्वपरिमार्यैः।

(d) कल्याणसंगम-शास्त्रिष्णु-परिमार्यैः कल्वै कारक्य-मुस्म्खल-विश्वस्वपरिमार्यैः।

No separate explanation is necessary, as the canons are embodied in the following exposition.
Theory of Atomic combination:—

The four kinds of Atoms are Earth, Ap, Tejas, and Váyu atoms, possessed of characteristic mass, numerical unit, weight, fluidity (or its opposite), viscosity (or its opposite), velocity (or quantity of impressed motion—Vega); also characteristic potential colour, taste, smell or touch, not produced by the chemical operation of heat (अपाकारण-क्षयरकन्सखः परमाक्षेऽवस्त्वै-उत्तेजनः गुलातुरुवलः चतुष्पातः).

A'kāsa has no atomic structure (विभय), and is absolutely inert (निरस्त्र), being posited only as the substratum of sound, which is supposed to travel wave-like in the manifesting medium or vehicle of Váyu (air). Only the other four Bhūtas unite (or disunite) in atomic or molecular forms. The orthodox view is that, the presence of Earth-atoms is necessary whenever chemical transformation under the operation of heat (प्राक्षेत्रपति) takes place.

Atoms cannot exist in an uncombined state in Creation (Śivāditya, Sapta-padárthi—vide commentary). where, however, it is noted that still atmospheric air is believed to be monatomic in structure, i.e., to consist of masses of atoms in a loose uncombined state—(सिखिनशासु औरायाक्षु मत्तक्षु यस्य अनारक्षछद्वासः)।

The atoms may combine in one or other of the following ways:—
1. One Earth-atom, by an original tendency, unites with another, to form a binary molecule (न्यायु ज). In the same way, binary molecules of the other Bhūtas are formed. The atoms are possessed of an inherent Parispanda (rotary or vibratory motion), and when they unite in pairs, so long as there is no chemical operation under the action of heat corpuscles, the original qualities of the atoms produce homogeneous qualities in the binary molecules.

The question as to the existence of a triad, a tetrad, a pentad etc. of atoms is one of the moot points of the Nyāya-Vaiseshika. The orthodox view is that, the primordial infinitesimal particles (atoms) start with an incessant vibratory motion (अत्वरसिसियस्वदानापरिधिनियमादिपरमाभि्ः, Raghunātha Siromani—गतिशीत्यमान प्रतावपदेशाः प्रतचीति, Udayana, Kusumāṇjali), and an inherent impulse that drives them to unite in pairs—a sort of ‘monovalency’, as it were, exhausted with the formation of a binary molecule. The binary molecules now combine by threes, fours, fives, etc. to form larger aggregates as well as the variety of elementary substances, the particular collocation in any case being not only determined by physical causes, but also serving to satisfy the ends of the moral Law in creation (अन्त, चतुर्). (द्वयु, र्षेष्ठंभिरायते श्चारी नियमो, न द्रामयां। ग्रह्यु, तत्त्ववम्। शास्तिः र्षेष्ठंभिरा-
A triad (Tryanuka), then, holds together three atoms (Anus), not three binary molecules (Dvyanukas) as on the orthodox hypothesis. Similarly with tetrads, pentads, etc. (वर्तविधा: परमाणु: चित्रितवाच्चित-वाच्चित; द्वाभां परमाणुभां द्वाः कार्याते निर्मिति:
These binary molecules are grouped by threes, fours, fives, etc. (नगरस्स, चतुरस्स) to form different isomeric modifications. The variety of Earth-substances is due to differences in the arrangements of the molecules, (e.g., their greater or less density, and, above all, their grouping or collocation अग्रह, अवयवश्यकत्व), which account for the specific characters (अपराजाति) manifested by these isomeric substances. ना (श्रोति) च खेलोद्यावसंस्कृतविशिष्टं अपरजातिविचक्कलेपां। प्रसांतपादु, श्रीवरस्विकृतम्। श्रेयं निपिंदलम्। अस्तिदश्रातु प्रशिक्षितवत्तिपरिपक्वः। परमात्मात्रसः अपराजातिव्यवस्थापि बहुतवशात् तथा तथा तेषां ब्यूः। यथा यथा स्वारागेषु, अपराण्यात्सो अवश्यने। स्त्रिधरो, कंदलिक, ibid.

श्रेयं स्मितता परमात्मातवशार्थितमिति हावत्। अस्तिद्यवहस्तस्वातं जवाहिद्यफरिक्षिपूत्। अवयवश्यकत्वः।
These original differences in molecular grouping leading to distinctions of genera and species, however mechanically or physically explained, come also under the operation of moral and metaphysical causes (चङ्ग, चंग), i.e., of ideal ends in the moral government of the universe, which are superimposed upon the physical order, but which do not come within the scope of Natural philosophy. An elementary substance thus produced by primary atomic combination, may, however, suffer qualitative change under the influence of heat (पाषाणपति).

The process is as follows:—(1) the impact of heat corpuscles decomposes the binary (tertiary, or quaternary) molecules into homogeneous atoms possessing only the generic characters of the Bhūta concerned;—(2) the impacts of heat particles continue, and transform the characters of the atoms, determining them all in the same way;—(3) the heat particles continue to impinge, and reunite the atoms so transformed to form binary (or other) molecules, in different orders or arrangements, which account for the specific characters or qualities finally produced. The Vaiseshika holds that
there is decomposition into homogeneous atoms, transformation of atomic qualities, and finally recombination, all under the influence of heat. The Nyāya on the other hand thinks that the molecules and larger aggregates assume the new characters under the influence of heat without decomposition into homogeneous atoms, or change of atomic characters (पिनुपात or पिठरपात).

तेषामनुसानेन विनाशः परिक्रमात्। भूभाववचनं अनवे स्थित
पाकपूर्वः कृपृवः दृष्टिविनिर्वादगुणोपचारसः प्रवेशः। क्राको-
रजुनकृत्वः तेन वेगवता वश्योऽवेव नोदनात् चोभिहातास् वा
नूनं घटायाः भूभेत् ब्रह्मचर्यं किर्यास्ते क्रियाते विभागः
विभागस्त् दूष्यार्चकसं बोगविनाशः। यद्विनाशस्त्रूयः
विनाशः। पकःः भूर्मचारिसुलभावजः। रत्नादिशुलभानर-
भोगन्यनवनः।—वहस्तित्वः माया। परस्सरं मः सुलभ द्रवीता-
प्रकाशेषे नाहयसेव घटाइकाय्यानारभेन। एवं तपनासपद्य-
भोगन्यनवन, भ्रामचारीसुवेष्, एव स्व नमः। दरीये चर्च घर्षेवेन
तेव्रता पच्चमानेषु, अन्नपानादिविष, रससचारात्माशेन परिच्छाम-
बुधगर्भस्त्रृष्ट्वा प्रावेश प्रतिविज्ञामुद्यादिविनाशः संभवत् हृत्।
(Jayanta. Nyāyamaṇjarī, भूसचतुर्य-पूर्वः पश्।) This is the Vaisēshika view, but Jayanta himself in-
clines to the opposite view:—महत्त्वविनिर्बन्धमान
कार्तिकेयत्र घर्षें: चारान्नात् चन्द्रेष्: चारानुपवेशोऽपि-
प्रयत्नः। अर्ज विभागवर्धनः। पिठरपातस्य एवेसकः। ibid.
The Nyāya view:—वे नीवारवनाले पूर्वः जूतिपर-
that impinge on the atoms, or the nature of the impact (विषयः-संबंध). (न ब्रह्मचर्यविषयं प्राप्तं क्षणम् च चापि तु पुष्पकारोपादिविषयं-चारत । वदूर्देवं पच्यते कार्यसंबंधः तथा ये पुष्पकारोपादिविषयं च: क्षणता विषयेऽ-विषयसंबंधः: कार्यसंबंधः उत्तरान् दृष्ट्वेकृत दृष्ट्वेकृत विषयानारम्भते। Vide also Udyotakara, III, 2, Sūtra 14. Cf. also Vāchaspati, I, 1, Sūtra 4. वेयित्वकारोपादिविषयं चापि तपानाश्च निर्भरस्त भौतिकारायणम् च वेयित्वसंबंधेऽवरुणोपादिविषयं चापि कार-खाना् भेदा भिष्णायो जायते स्मृति विश्वान:।

Now when the atoms have all been determined in the same way, they begin to recombine again under the impact (or impulse) of the heat-particles in binary molecules, (or tertiary, etc.), and these in higher aggregates. It seems to be generally held that, at the final step one or more atoms of one constituent substance unite with one or more atoms of the other constituent substance or substances to form a molecule of the com-
pound; but the question is not of much significance for Mono-Bhautic compounds of the first order, as, in these cases, the atoms have before this all lost their distinctive characters and become homogeneously transformed. The compound so produced will possess the new characters of the transformed atoms, so far as taste, colour, smell, etc. are concerned, but as the molecular arrangement or structure (अवयवसंबंधितम्) may vary, different compound substances may result from the same components.

(b) Mono-Bhautic compounds of higher orders:—Again, Mono-Bhautic compounds of the first order may chemically combine to form higher compounds, and as the ultimate Bhúta substratum is the same, the process of decomposition and recomposition will be essentially the same as before. The only doubtful point is whether in this case the component compound substances are broken up only into their constituent molecules, or into the original homogeneous Bhúta atoms. Some of the later Vaiseshika Scho-
liasts hold that the latter happens in every case of chemical composition, however complex, but the earlier Vaiseshika conceived that in the case of compounds of compounds, the decomposition does not proceed so far as the original Bhúta atoms; but that it is the specifically determined atoms constituting the molecules of the component compounds that are transformed under the impact of the heat corpuscles; and then one such transformed atom (one or more according to another version) from the molecule of one component unites with one similarly transformed atom (one or more according to the other version) from the molecule of the other component. Prásastapáda, the great Vaiseshika Doctor, holds this view. When, for example, in the fertilised ovum, the germ and the sperm substances, which, in the Vaiseshika view, are both isomeric modes of Earth (with accompaniments of other Bhútas), unite, both are broken up into homogeneous Earth-atoms, and it is these that chemically combine under the animal heat (and bio-motor
Energy, चावु ) to form the germ-plasm (चवच). But, next, when the germ-plasm develops, deriving its nutrition from the chyle (blood) of the mother, the animal heat breaks up the molecules of the germ-plasm into its constituent atoms (वचचार्या-पर्सा), i.e., into atoms specifically determined, which by their grouping formed the germ-plasm, and then these germ-plasm atoms as radicals chemically combine with the atoms of the food constituents, and thus produce cells and tissues. (सघुतुपन्‌पांकौ: चचवचार-रम्भा‌क्षरर्माक्षुभ: शचद्वशात्‌ चपजातक्रिये: चाहारपरसाखुभि: भह सन्ध्य गहरोरानर-मारभ्यते चतुष्णा चचपा। पितः युक्त मात: गोचिष्ठ: तजा: सव्रितापानमहं जतारानव-सम्भवात्‌ युक्तरोश्यासर्वनबेशु परसाध्यु पूर्वभुपातिर्दिव्यनाशे चाल समानज्ञानतूर्वतूपसासे द्रुसुपादित्र-प्रक्रमनेष्व कलषगहरीरोरुपाससे।। ......

...तथा चाौंतराहारर्ग: नामवा संक्रान्ति अचद्वशात्‌ तथा पुनर्मृत्तरानववध्यात्‌ कहर-र्ग: १६१४४००४७४० स्विताविभागार्थिंयावेन कचव-गरीरे नस्ते सघुतुपदपांकौ: चचचार्या-
In this hypothesis, it is assumed that the atoms are similarly transformed, *i.e.*, become endowed with the colour, taste, smell, *etc.* of the product (the cell or tissue), the moment before the chemical combination takes place. Similarly, when milk is transformed into curd, one view is that the transformation takes place (under internal heat) in the constituent atoms of the milk molecules, atoms specifically determined as milk, and not in the original atoms of the Bhūta (or Bhūtas) entering into the composition of milk.

(Cf. एवं महाद्रुप्तारञ्जः परमाबुधिरेव द्वधा-रभ्यते। एक्षिक्ष्रेव द्वधारक्ष्रेव पर-लाखुभिर्नेतोतारन्तः प्रति रिसः। Nyāyabodhinī, on Annam Bhatta’s Tarkasaṅgraha.) Cf. Dinakarī, on the other hand—इत्युत्तोद्वरुप्त्र्यांसंज्ञातेर्थिः तथा (स्र्वः:)। In these cases, the atomic contact is called constituent contact.
(सार्वभौमिक), and all the atoms are equally regarded as material causes (यपाद्यानकार्य or समकालिक) of the compound.

B. Hetero-Bhautic ‘quasi-compounds’.—The Nyāya-Vaiseshika maintains that in the case of bi-Bhautic (or poly-Bhautic) compounds, which are only quasi-compounds, there is another kind of contact between the heterogeneous atoms of the different Bhūtas, which may be called dynamic contact and is distinguished in its operations as Upashtambha, Vishlambha or Avashla-mbha (उपशत्मक, विशत्मक or अवशत्मक). In some cases, it so happens that the atoms of different isomeric modes of the same Bhūta do not chemically combine under the mere application of heat;—they require to be surrounded (and ‘excited’, ‘energised’) by atoms of different Bhūtas. For example, in the case of the oils and fats as well as of plant saps and fruit juices the Earth-atoms must be dissolved in water (Ap), and it is only when the water-atoms (Ap-atoms) congregate round the former that dynamic intra-atomic
forces are set up, and the Earth-atoms (with the water atoms in dynamic contact) now take on peculiar infra-sensible characters (colours, tastes, smells) under the impact of the heat corpuscles, and then, under further impact, fall into groupings or collocations (of a very peculiar nature, to be presently explained) which determine the nature of the composite substance thus produced. Here it is the water-atoms that are dynamic (उपश्चत्र), and excite the Earth-atoms, and these substances, oils and fats (सैवगरं and छलवरं), as well as acids (उम्ब्लं) are, because of the Earth radicles regarded as Earth-compounds (or Earth-substances). (पाकज्ञ-समाविष्टगंधारसिसपार्टिनाथ: परमायुक्तिसुखं नार्दिकयेकं छसादिव्र-भारयते। तम च उपवस्त्रालय निमित्ता-बाप्पचा: पानीयावयवः। तेषां संयुक्तसमवावेन छसादियोपययते। तेषां स्रीरादिदु, पार्ध्विल्क-पीतम्बसी:। तेषा भीमानवेनमज्ञातुं छचवतं Udayana ). In the above instances, Ap (water) acts as dynamic (Upash- tambhaka, (उपश्चत्र), but Tejas
and Vāyu can also act in the same way on Earth-particles. Conversely, Earth-particles may act dynamically on the atoms of the other Bhūtas. For example, in the case of mercury and the metals which are conceived in the Nyāya-Vaiseshika to be igneous bodies (in fact they are supposed to be formed under the subterranean heat आकारण), the Tejas corpuscles are believed to form the radicles, and the Earth-particles are dynamic (उपपट्टयन). (तुष्कन्ति निरणां भायमाणं मिन पूर्वव्रूप जन्मति। तेनैव दृष्टग्रामवेश प्रतिबिप्पात उपपट्टयनेण पार्थिवभागः संग्रहश्च एवानुवर्तने, यतु पुष्पाकारिणा रक्तार्तिः हस्यं स्मृतिभूसाबिभावकसददृष्टव्यक्तप्रयमाने एवेन पार्श्वादि व्याख्यातम्। Udayana, Kiranaivali, हेमज्ञानिक्षप्यम्। Cf. also वैज्ञानिक सुवर्णम् नेवायुब पार्थिवोभाग उपपट्टयन यष्टवर्गः।)

It may be here noted that Gaṅgesa, the author of the Tattvachintāmaṇi, conjectures that even gold can be evaporated or made to disappear by the application of intense heat;
But while every Bhúta can act dynamically as उपदंक, ‘energiser’, ‘exciter’, it is the Earth—Bhúta alone which is capable of exercising the power of arrest or inhibition of molecular motion or the motion of particles due to gravity as in fluids (Vishámbha, विश्वंभ), or the power of counteracting the tendency in a given set of atoms to fall into a peculiar order or group (खृष्टिविरोधित्वम्).

(गच्छितविश्वम् जन्म कृताङ्गात्मकं गति रूपं बौद्ध वा विश्वांशः।) Udayana, Kiranávalí, दृष्टिनिद्रिष्ठम्। विद्या-विज्ञानस्तत्त्वयथाकृतिरादग्रहितब्याप्तम्। खृष्टिविरोधित्वम् ग क्षाराविज्ञानस्तत्त्वसमर्पस्तं बन्धवत्सलम्। Vardhamána, Kiranávalí-prakása, ibid.)

Oils fats, milks—Bi-bhautic quasi-compounds, with Ap as energiser:—Oleaginous substances
are divided by Udayana into (1) oils, derived from vegetables, (2) butters derived from milk, and (3) fats derived from animals. The medical schools, as we have seen, recognise animal oils as distinguished from vegetable oils. Vegetable fats (*e.g.* विद्युक्तस्त्र) are also mentioned. Vāchaspāti in the Tatparyyatīkā contends that mustard oil has not the flavour and smell characteristic of the true oils (sesamum, linseed *etc*.), and is classed with the latter by convention. Judged by the flavour test, Aṁikshā (the casein substance formed by mixing milk-curd with hot boiled milk) is to be classed with milk substances. So also Takra, whey,—but Vājina, the thin fluid that is left after the Aṁikshā (casein substance) is separated, cannot be classed as milk. It may be added that the milks and curds as well as oils and fats derived from different species of vegetables or animals are supposed to differ in their ultimate structural arrangement, and therefore in kind; but Vallabha thinks that the ghee (clarified butters) prepared from different kinds of milk are of the same kind; in other words, the milks and curds are ‘polymeric’, the ghee (clarified butters), ‘isomeric’, using these terms as before, in a loose general sense.
III. Mixtures like soups, solutions etc.: — A soup is a physical mixture. When meat is boiled in water, there is the application of heat, with chemical changes in the meat, but the combination of meat-particles and water-particles in the soup is only physical combination, and not a chemical one. It is of course not a true compound, neither is it a quasi-compound, like milk (in which the water-particles are ‘energisers’ of the Earth-particles). Milk, for example, retains its milky substance, when it coagulates or becomes solid, (this of course is also the case with mono-Bhautic substances whether elementary or compound, e.g. water, which becomes ice,) but the substance we call a soup or solution ceases to be a soup.
or solution, the moment it solidifies. Udyotakara notices gruel, baths, and lyes (alkaline solutions) as mixtures of this class (एतेन पावासार्थाविषेषावकारार्थः पत्युःः। Vārtika, Chap. I, Aṅhika I, Sūtra 14). युगे हि नाम चतुर्दशायाजानां द्रव्याः कालिविधेयानुपस्ते सति द्रव्यान्तरसंश्यां द्रव्यास्त्रयां व: संबोधः व वृष दस्ति। एतेन पावासार्थाविषेषावकारार्थः पत्युःः। Udyotakara, Vārtika, Chap. I, Aṅhika I, Sūtra 14. Vide also Vāchaspati’s comment: उपयुक्तपावाजानां सैः कृपिः वा पिद्दामार्थान्वितावयवां द्रव्यान्तरेः लोकन संवुःः नागीरायणसंस्कारिा नामां न चालै सहसा इत्युः द्रव्यान्तरसंश्यानुः सतोःः। ए च संबोधगर्भे-एव लोकमान्सवेरः अयावे विकासीमथेयो वातावरणार्थः। नामिः द्रव्यालोक्तं तोमस्त्रोः स्वयं चीरालोणमधित्तेत वुःः। तोमस्त्रोःः कार्यविन्यासे चीरुद्विभिधयमेहयोऽवस्थार्थः। तेह स कार्यविन्यसेः न तृषुमुद्धिभिधयमेहयोः दस्ति सम्भवतेऽऽव तोमास्त्रोऽवृःः दस्ति नाथ्यम्। ए च तनुभवसिः संबोधिः अयावे अतिरिक्तः। Vāchaspati, Tātparyyatikā, ibid. For salt and alkaline solutions, vide Kiranāvalī—चतुर्दशायाजानां द्रव्याः कालिविधेयानुपस्ते सति द्रव्यान्तरसंश्यां द्रव्यास्त्रयां व: संबोधः व वृष दस्ति। एतेन पावासार्थाविषेषावकारार्थः पत्युःः। Udayana, Kiranāvalī, अयावे अतिरिक्तः। Chemical action and Heat:—The operation of heat is of course universally implied in chemical
combinations. Where the application of external heat is wanting, Vātsyāyana, the great Doctor of the Nyāya, points to the operation of internal heat.

(c.f. द्रष्टिकोषात्र चंप्रायात्मका स्थितिः स्थितिः चतुर्वेदी द्वितीयोत्तरः—Vātsyāyana-Bhāṣya, Chap. IV, Aṅhnika 1, Śūtra 47). In the case of combustion, we have seen Vijñāna-bhikshu explain the heat as latent in the Earth-substance, the fuel, from which it breaks forth. Udayana points out that the solar heat is the source of all the stores of heat required for chemical change in the world. The change of colours in grasses, for example, is due to Tejas, in the form of latent (invisible) heat, not in the form of Agni; and the cold in winter cannot take away this store derived from the Sun. (क्षारास्वभावार्थे इति क्षपितप्रायान्‌

dharmamāhāt; स नृष्माण्यपक्षेऽद्य तेजस्वर वर्त्ते; || तत्त्वम्

c पाने अरितिश्व विश्वास मान।। न क्रियति द्रष्टिकोशातः प्रभावते। न
fhi सौरस्य तेजस्वं तेजोक्षमप्रायात्तोहि सार्वभादुपमः चक्रते।

अथ विकारे अभ्यासित्प्रपातिर्विश्विन्धः सीतष्टिन्नविषयं एव इंश्रण्यं

तहादु से विदियो बाधो सा। अथ क्षपितप्रायान्‌

माने वैव जनः साध्ये तद्रकम्। तस्य द्विभवध्विन्नान्‌

प्रायाप्रायायं नवं शिवाविद्विल्लावात् भवात्वाद्वा तेजोभवस्व

निर्धारितसन्प्रथमात् बनित्वात्।। Udayana, Kiranāvali
dhirṣāpravāśe adprāśe धन्यम) Similarly, it is under this solar heat that the unripe mango ripens, i.e. changes
colour, taste, smell etc., showing that there is chemical transformation or subtile decomposition and recomposition going on; and this is also the case with the rusting of the metals, which is a combustion due to the solar heat (हृदय पाष) even as the conversion of food into chyles and of chyle into blood are instances of chemical action due to the internal animal heat (जष्ठनाथ or धौस्यं तेजः).

But the kind of contact with heat-corpuscles, in other words, the kind of chemical action (पाष) which transforms colours is supposed to differ from that which transforms flavour etc. (विषवशातेजः संयोग and पाष) and this last from that which produces a change of smell, or tactile quality. (पाषो गाम विजातोयतेजः संयोगः। स नानाजातियः। हृपजनो विजातीयतेजः संयोगसद्भेदया रवजनजो विजातीयः। एवं खर्मीहृद अधिनि लघा। एवं प्रजातिः भिषाभिन्नजातियः पाषः। वायूयं नासक्यम् कामणियः। तधार्थः तवपुष्पं मन्तस्वतः। खादृत मधुसच्चविजातीयतेजः संयोगात् पूव्विन्स्वरतिकपनाय हृपानलस्या पीतादेश्तपतिः पूव्विर बश्य अबुलीश्वानुभवात्। कार्यः पूव्विन्स्वरतिकपनाय स्वरुप्तचा विजातीयतेजः संयोगकपालकमात् पूव्विन्स्वरुप्तस्मातः बस्ति विजातीयतेजः संयोगकपाकमात्। नासक्या रवजनजो विजातियः एवं गन्धजनको विजातियः यवाकृत्तियः। प्रतादधृति पराित्स्य बस्ति पूव्व गन्धमाये विजातीयपालकमात् सुरभिन्नोपश्च:। एवं
Heat and light rays are supposed to consist of indefinitely small particles which dart forth or radiate in all directions rectilinearly with a sort of conical dispersion and with inconceivable velocity. They may either (1) penetrate through inter-atomic (or inter-molecular) spaces as in cases of conduction of heat which when applied under the pot boils the water, or fries the paddy where there is no chemical action in the pot, no decomposition and recomposition of its atoms, no change in the molecular collocation; or, as with light rays in cases of translucency or transparency (क्षेता) penetrate through the inter-atomic spaces with Parispanda of the nature of deflection or refraction (तिक्र ग्रंथन, Udyotakara), in the same way as when fluids penetrate through porous bodies (ततः परिसंदृष्टः सिंह ग्रंथन परिश्रः: पाति क्रसि—Udyo-
takara, commenting on Vátsyáyana's परिखन्द-परिख्यानः, Sútra 47, A’hnika 1, Chap. III.) or (2) impinge on the atoms, and rebound back—which explains reflection (धूपन, जिरक्षिप्तन—Varáhamihira, रथ्मवानतन—Vátsyáyana) or otherwise be obstructed by the atoms in their path, which would explain degrees of opacity, the casting of shadows, etc., all these operations being also physical, and unattended with decomposition and recombination or alteration of molecular grouping, or (3) lastly, strike the atoms in a peculiar way, so as to break up their grouping, transform the physico-chemical characters of the atoms, and again recombine them, all by means of continual impact with inconceivable velocity, an operation which explains all cases of chemical combination.

(आपन्यो फि तेजसो जावानासनेन उपासितय: बत्त प्राणीन-पक्षः हादविन्यास एव भगवति सब्बाश्वाषिनि मनोदेशं जाइश्वराशवभवानो कौषिक्यानां। (Udayana, Kiranávalí, तेजोनिक्ष्याम्—taken from Váchaspati, Tátparyayatíká, प्रश्चवचवचक्तम्।) Cf. also (पाच्छं तेजः नेगवशा जायिनेन तेजसः न प्रतिम्नन्ते। Váchaspati—वाचस्थेपि पिरीख्तपण तेजः: प्रििि प्रावादोदयं थापोदित। तत् भएद देशोऽः इव्यापितान्। काचायत: प्रहर्तस्य न क्षपित-मायाप्रिधायावरं प्रस्वसापसि किं द्रित विषमेदानुविधाविनम्। ibid. Cf. प्रश्चवचादानालिकोलविधिरं प्रवादः खाणात्वम्।
Udayana, in reply to the objection—

\( \text{उदयन, इबिद.} \) Definition of त्रिज्या—

उदयनालाः त्रिज्या त्रिज्या त्रिज्या त्रिज्या त्रिज्या त्रिज्या त्रिज्या त्रिज्या.

Udyotakara, Chap. III, A'nhika 1, Sutra 38. बाधित्यानि: स्फोटवृत्ति: दाहिगुर्गच: सुत्र 47, where Udyotakara notes—

वाचास्पति विभागः—वस्य द्रव्यस्तावशतानां अज्ञातानां अज्ञातानां अज्ञातानां अज्ञातानां अज्ञातानां अज्ञातानां अज्ञातानां अज्ञातानां.

Cf. Vâtsyâyana on Sutra 47, A'nhika 1, Chap. III. On the other hand in chemical combination, धन:प्रेषित:—

कलापिणीति। तत्व वेगवता वेगवता वेगवता वेगवता वेगवत।—Jayanta, Manjari, भुवते भुवते—

For opacity, shadows, etc., vide खास तत्व: परमायुक्ता परमायुक्ता परमायुक्ता परमायुक्ता परमायुक्ता परमायुक्ता। वल य खास खास खास शास्त्री तत्त्व पूर्वके।
HINDU CHEMISTRY

Udyotakara, Chap. IV. Āhnika 2, Sūtra 25. For reflection, and its laws, I quote passages in my paper on Hindu Physics and Mechanics, to which the student of the history of Optics is referred.

Arrangement of atoms in Space:—The Nyāya conceives atomic magnitudes as Pārimāndalya, a term which indicates a spherical shape. (निम्न परिमाणबल—परिमाणबल्य रामाखल्य—Saṅkaramisra).

To conceive position in space, Vāchaspati takes three axes, one proceeding from the point of sunrise in the horizon to that of sunset on any particular day, (roughly speaking, from the East to the West);—a second bisecting this line at right angles on the horizontal plane, (roughly speaking, from the North to the South), and the third proceeding from the point of their section up to the meridian position of the sun on that day, (roughly speaking, up and down). The position of any point in Space, relatively to another point, may now be given by measuring distances along these three directions, i.e. by arranging in a numerical series the intervening points of contact, the less magnitude or distance being that which comes earlier in this series, and the greater that which comes later. The position of any single atom in Space with reference to another may be indicated in this
way with reference to the three axes. But this
gives only a geometrical analysis of the concep-
tion of three-dimensioned Space, though it must
be admitted in all fairness that by dint of clear
thinking it anticipates in a rudimentary manner
not only the foundations of solid (co-ordinate)
geometry, but also of the geometry of position,
and especially the conception of Space as a
Manifold, which alone can serve as the basis
of a generalisation comprehending all different
possible kinds of geometry, Euclidean and non-
Euclidean. (एकधेरेप दियः चामिकोदवदेशभास्मदशब्रेगसंतुः यः च इतरक्षाहृतविन्द्रालप्रक्षेपसम्बोधः परमाशः पूर्वः एवताटे
त्वाक्षरमदेशभास्मदशब्रेगसंतुः यः च इतरक्षाहृतविन्द्रालप्रक्षेप- संबोधात् परमाशः परशः तौ च पूर्वः पश्चिमः परमासूः
अपेक्षः यः अवर्त्त्याक्षरमदेशभास्मदशब्रेगसंबोधः स मध्य-
व्यः। एवेनतरोऽशी तिथिग्नेशवयं विभीसे सम्भय चार्जते न ब्यवहीतः पार्श्वाक्षः कै त्रिष्कोवतः परमासूः। एवम
मध्यन्तरीयतिथिं विध्वंसविद्वरोऽवरोऽवरे च ब्यवहीतः च च च एवरण च च प्रमोऽवरे
इत्यादः। संयुक्ततत्तवोऽगाहपुष्पयति व मतिन्तरीयतिथिं पूर्वः संयुक्ततत्तवम् च अथवः परमासूः च च भूयस्वम्।
Váchaspati, Tátparyyatiká, Chap. IV. Áhniaka 2, Sútra 25.

The original physical arrangement of atoms is
also given. Each atom is in contact with six other
atoms, which gives a cubical arrangement. एवं
This is the typical primordial arrangement, and variations in the collocation of atoms and molecules (ब्रूह, अवबंधित्वेष), as we have seen, were conceived to account for the variety of isomeric modes of the same Bhūta, as well as of mono-Bhautic and poly-Bhautic compounds.

The molecular arrangement in the case of bi-Bhautic compounds is very peculiar. Two substances, say Earth and Ap (water), form a quasi-compound, first, and each substance breaks up into atoms, one atom of Earth comes into contact with one of Ap. But the two do not form a binary molecule. Instead, this contact of heterogeneous atoms leads to a curious result. The atom of Earth combines with a neighbouring atom of its own class, and forms a binary molecule. Simultaneously the atom of Ap combines with another Ap-atom, and forms a binary molecule. Now the first binary molecule links on to the atom of Ap, and similarly the second binary molecule links on to the atom of Earth. The moment after, the two binary molecules take on the physico-
chemical characters of Earth and Ap respectively, and simultaneously with the assumption of these physico-chemical characters, the binary molecules enter into complex contact (संबंध व्यंग्य). In all this process, work is done only in the first instant, in the contact of an atom of Earth with one of Ap—the resulting contacts of atom with binary molecule and of the binary molecules with each other, involve no further expenditure of Energy. Thus we get a particle holding two binary molecules (of Earth and Ap respectively) in complex contact, and such particles continue to be formed. In this way the particles of the two substances arrange themselves, and the peculiarity of this molecular arrangement explains the resulting mixed or compound qualities of this class of quasi-compounds.
The whole process may be graphically represented as follows:—

\[ \text{E} \] = an atom of Earth.
\[ \text{W} \] = an atom of water (Ap).
\[ \text{W} \] = a binary molecule of water (Ap).

Molecules of a bi-Bhautic quasi-compound;—graphic formula of complex contact.

I will conclude this account of ancient (and mediæval) Hindu chemistry with a note on the conception of molecular (atomic) motion, Parispanda, and the different varieties of such motion which were conceived to account for the physical phenomena of sound, light and heat. Any attempt to differentiate rigidly between Mechanics and
Physics on the one hand and Chemistry on the other at this primitive stage would be an idle affectation. My paper on Hindu Mechanics and Physics will give a detailed exposition in a separate treatise.

Parispanda:—Resolution of all physical action into motion:—

Parispanda sometimes stands for motion molar as well as molecular, but more often for the subtile motion of atoms or molecules. The radical meaning of the term is whirling or rotary motion, a circling motion, but it may also include simple harmonic motion (e.g. vibration). All action, operation, work (कार्य, ग्रापार) is ultimately traced to this form of subtile motion lodged in the atoms or in the matter-stuff. The Vedánta, for example, speaks of a cosmic vibratory motion (स्वर्गन्धन्यकृतिपरिक्ष्यन्न—Saṅkara).—A’kāsa, in the Vedánta, as we have seen, is the first stadium in the evolution of Matter, which gives off Vāyu, which gives off Tejas, and so on; but A’kāsa (Ether) itself passes through two stages before the emanation of the Súkshmabhúta Váyu:—(1) the motionless ubiquitous primordial matter-stuff (answering to the Sánkhya Bhútádi) called Puránam kham (पुराण खं); and (2) a subtile integration, the pure unquintuplicated Súkshmabhúta called Váyuram Kham.
(वायुः) (answering to the Sāṅkhya Tanmātra stage). It is this subtle Akāsa, in its Tanmātric integration, i.e. in the derivative form, which is subject to an incessant Parispanda. The gaseous stage of matter (the Vedāntic Vāyu) is indeed matter in a state of Parispandic motion (वायुः परिस्परवाल्कलनः—सांकर). So also the bio-motor and sensori-motor principles apart from the directive Intelligence of the Self (प्राणिक वरिष्ठन्द्र—लक्षणारेव—सिद्धीम् अन्यान् लक्षणम् तत्सम्भे भवःसन्तः—सांकर). The Sāṅkhya also conceives this Parispanda to characterise every process and phenomenon of cosmic evolution (वायुः सक्षम वरिष्ठन्द्र—Vāchaspati, Kaumudī). Bhūtas, organisms, mental organs, as modes of Prakṛiti (considered apart from the Intelligence of Purusha) are all subject to this Parispanda (प्रभृतिबो देहं त्व्यजये देहानां द्वादशतः दृश्य लैऽो परिष्चन्द्रः। परंततः त्वत्प्रभित्वमः परिष्चन्द्र: प्रभृतिः एव।—Vāchaspati on Kārikā 10).

On the other hand, Prakṛiti as the Avyakta, the a-cosmic, the un-manifest ground, with resolution only of like to like (सत्यम् रिवासम्), is devoid of all Parispandic motion (वायुप्रणतस्याधिपि परिष्चन्द्राधिपि क्षिप्या। वायुप्रणवरिष्चन्द्रो नावल। ibid. on Kārikā 10).

The Nyāya-Vaiseshika finds Parispanda in all
forms of matter, except Ākāsa which, in that system, is non-atomic and incapable of any change or activity (निर्विकाल). But all atoms from those of Vāyu downwards, are in incessant motion. The world at bottom is an infinitude of continually whirling (or vibratory) particles (अवरतवरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्कन्तकाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्ककाधानावरिष्क
activity. (परिसंहथ यत् सौतिथो व्यापरः करोतर्थः। सबी-निर्द्रव्यः व्यापरः नालोति नूतसे।...........सळात् बारस-चक्रेश्च पवित्रा जन्तुः पवम्। न पुनःचक्रनांदयो व्यापर-श्रवण्ये। जयान्ता, न्याय-मण्डरी, अह्निका I )

The effect (no less than the action) is, in all cases of material causation, the resultant of the combined motions of the various (material and efficient) causes involved (c.g. in the case of पांक्ष-संयुंद्र-चेताविनिविनिवरपरिसंहथ यत् विगुप्तपावार्त्तिकः पांक दत्तुवच्ये। ... कथ व्यापर एते: सबे: संयुक्तम् साध्ये। नं फेनापारातु व: नं विष्णु संयुक्तम् साध्यैवम्।—जयान्ता, न्याय-मण्डरी, अह्निका I ).

But, in the Nyāya-Vaiśeshika, though all action of matter on matter is thus resolved into motion, conscious activity is sharply distinguished from all forms of motion, as against the Sāṅkhya-Vedānta, which, as we have seen, considered every thing other than Intelligence, the Purusha or the transcendental Self, to arise in the course of cosmic Evolution, and therefore to be subject to Parispandic motion. (क्षिताविषेष एवायें व्यापरो चाहुरासरः। सत्ताःतस्ववहित्वूऽ विश्वविश्वविविलक्षम्।—Quoted in Jayanta’s Nyāya-maṇjarī, A’hnika IV).

Santāna, i.e. Gati-santāna (including wave motion and current motion or convection); Kampa santāna, Spandana, (vibration):—Charaka notes
three kinds of santānas, serial motions, *viz.*, those of water, sound and light (अलस्वन्तान्, गंधर्वन्तान् and विज्ञवन्तान्). Chakrapāni points out that a wave of sound travels more rapidly than a wave of water, and much less rapidly than a ray of light. In Hindu Mechanics, a current of water (downward flow, खल्लम्म) is conceived to consist of particles moving in an uninterrupted series under the action of gravity and fluidity (कुल्लम्म and दवल). A ray of light implies the rectilinear propagation of indeterminately minute corpuscles, in all directions, with inconceivable velocity, and a sort of conical dispersion (बिन्नलो किरण वेगातिशय: तेजः:पररत्न व्यवृणति प्रस्थरतात्।
Udyotakara—Vāchaspati). A wave of water (वीचित्ररक्षः) implies the transmission of vibratory motion in the water particles. (Cf. Jayanta—पतंजलिनियोगिन्यंद्र–
संदोहस्त्पनकमः। Ahnika II.) A wave of sound is conceived by some on the analogy of a wave of water (वीचित्ररक्षः), only the air-waves (cf. the Mīmāṁsā) or the sound-waves in and through the vehicle of air-waves (cf. the Nyāya-Vaiseshika) travel by concentric circles not in one but in all planes. (N.B. this assumes transverse waves). Others hold that the air-waves (cf. the Vākyapadiya) or the sound-and-air waves (cf. Udyotakara) are propagated by the transmission of the vibration in all directions, leading to conjunction and disjunction of air-particles, so that the wave may be said to expand by alternate concentric
spherical layers of rarefaction and condensation (N.B. this assumes longitudinal waves).—
(Savara-Bhāṣya 1-1-17) The Vākyapaḍīya describes articulate sounds (Varṇas) and indeed all sounds (sabdas) as only forms of air set in motion, with rarefaction and condensation (प्रचब), and capable of variations of velocity and configuration (स्वरित्वभिन्नता वायुः मद्यं प्रतिपद्यति। तत्त्वकार खलामयोंत देवतारघबर्णम्। संविधान विविधाने सार्वत्तत्रिपि मृत्तंदः—Vākyapaḍīya, Kānda 1. Sloka 109) (vide my paper on Hindu Mechanics and Physics). (For the Hindu doctrine of scientific Method, vide Appendix; for certain interesting recipes of chemical technology, vide Addenda).

I had intended to conclude this survey of Hindu Physico-chemical science with a comparative estimate of the evolution of scientific ideas in the culture-history (kultur-geschichte) of the Chinese, the Greeks and the Arabs, as an Essay in the historico-comparative method of investigation (vide the Preface to my Comparative studies in Vaishnavism and Christianity for a correction of this method), but space forbids, and the reader too, I fancy.
The Date of
Rasaratnasamuchchaya.

While the present volume was about to issue from the press, Mr. T. G. Kála, Editor of the Marhattá Journal “Samálochaka”, sent us a critical notice of R. R. S. As there are some important historical facts brought to light and as the date of this work arrived at from quite independent sources tallies with that assigned by us (Vol. 1. Intro. LXXXIX), we make no apology for reproducing its substance in a condensed form.

Charpañi or Charpa/ínátha of the Nátha school is mentioned in the R. R. S., (see VI, 58, Poona edition), as also king Singhana.

The Navanátha Saktisára, a Marhattá work by Narahari Mála, gives some legendary information about this Charpatínátha and speaks of him as a contemporary of Matsyendranátha. On the left has been given the geneology of the pupils of Matsyendranátha. The last, Cánádev or Cánéshvar, was the celebrated Marhattá Saint and author of a commentary on the Bhavácintu called Cánéshvarí.* It was written in Saka 1212, i.e., A. D. 1290. So Matsyendrá and Charpatínátha must have lived at the beginning of the thirteenth century A. D.

* See the concluding portion of Cánéshvarí, a Marhatta work.
The R. R. S. which mentions the Siddha Charpai must be therefore later than the first half of the thirteenth century A. D.

Among the Yâdava kings of Devagiri or Daulatabad, there were two kings by the name of Singhana. Taking the Singhana mentioned by R. R. S. to be the second, we are required to place the composition of the work in the latter half of the 13th century. On the whole, the R. R. S, may be safely taken to be a work written about 1300 A. D.

THE WEIGHT OF AIR.

(By Principal B. N. Seal).

Experiments were of course conducted for purposes of chemical operations in relation to the arts and manufactures, e.g., metallurgy, dyeing, pharmacy, perfumery, cosmetics, horticulture, and the making of glass (lenses and mirrors of various kinds are mentioned, the spherical, oval—ਲ਼ਚਿ and ਵਾਕ਼, being well-known—Pliny indeed mentions that the best glass ever made was Indian glass). But of Experiment as a Scientific method of Proof or Discovery, the instances are rare. I may note one
interesting example in Udayana's Kiranávali, relating to the weight of air. Udayana argues that air must be a distinct and independent Bhúta, for if air were made of the Earth-Bhúta, it would have weight, and it has none. To prove the absence of weight, he refers to an experiment. A small bladder made of a thin membrane, filled with air, will not cause a greater descent in the scale than the same bladder weighed empty. Hence the air possesses no weight. Then Udayana makes an interesting statement. It may be objected, he says by one who accepts the weight of air—that this argument is inconclusive. For a counter-experiment may be suggested. The balloon filled with smoke (or gas, घूम) rises in the air, whereas air-filled balloon comes down. This would go to show that air has weight. Udayana replies that this would only show that both smoke (gas, घूम) and air have no weight. The Hindus appear to have been ignorant of the principle of Archimedes, at least as applied to gases. Vallabhácháryya in the Lilávati speaks of a peculiar resistance to sinking (or gravity) exercised by water, which explains the tendency in certain objects to float or to come up to the surface of the water, but the description shows that he had no clear ideas on the subject. Cf. Udayana, Kiranávali, गयुनिस्थवस्त । Cf. also Vallabhácháryya, Lilávati.
APPENDIX.

On the Scientific Method of the Hindus.

(By Principal Brajendranath Seal.)

The Doctrine of Scientific Method:—A study of the Hindu Methodology of Science is absolutely essential to a right understanding of Hindu positive Science, its strength and its weakness, its range and its limitations. Apart from this rigorous Scientific Method, Hindu Chemistry, such as it is, would be all practical recipe, or all unverified speculation. This, however, would be a very inadequate and indeed erroneous view of this early achievement of the human mind. That the whole movement was genuinely and positively scientific, though arrested at an early stage, will appear from the following brief synopsis of the Hindu Methodology of Science.

Criterion or Test of Truth:—The ultimate Criterion of Truth is found not in mere cognitive presentation, but in the correspondence between the cognitive and the practical activity of the self, which together are supposed to form the circuit of consciousness. That knowledge is valid which prompts an activity ending in fruition. (Cf. the distinction between विश्वासितवृत्ति and विश्वासितवृत्ति. Also, मनोपतितोऽयं महत्तेच्यो भवद्धान्यायत्वम्भवत्मकम्—Vátsyáyana).
Truth is not self-evidence, not the agreement between ideas, nor the agreement of the idea with the reality beyond, for this cannot be attained directly, but the harmony of experience (समान), which is implied when the volitional reaction, that is prompted by a cognition and that completes the circuit of consciousness, meets with fruition, i.e., realises its immediate end (cf. Sṛṅharṣa, Khandana Khanda Khāḍya on the relation of प्रमन to चौराष्यवाद). This is the material aspect of Truth. The formal aspect is given in a principle which governs all presentations in consciousness, and which combines the three moments of Identity, non-Contradiction and Excluded Middle in every individual cognitive operation [तद्र तत् परिप्रेक्षणस् (identity) नवद्व नवक्षणस् (non-contradiction) वत्तीय-प्रक्तारामार्थं व पूर्वत् (excluded middle) हि एकाभाव-व्याप्त:—Jayanta, Nyāya-Manjarī, प्रथमवेदीपातिक्षरम्].

Perception:—The conditions of perception, and its range and limits, were carefully studied. The minima sensibile (e.g., the minimum visible, the Trasarenu, the just perceptible mote in the slanting sunbeam), the infra-sensible (अभव्यतः स्रष्टा, sometimes termed चतुर्बन्ध), the obscured (अविलुक्त, e.g., a meteor in the mid-day blaze), and the potential (अवस्थित), are distinguished; but finer instruments of measurement were wanting, and this was a principal cause of arrested progress. It may be noted that the measurement of the relative pitch of
musical tones was remarkably accurate and original (vide my Paper on Hindu Mechanics and Physics).

Observation (वाचस्पति—Vāchaspati and Udayana):—
The entire apparatus of scientific method proceeded on the basis of observed instances carefully analysed and sifted. This was the source of the physico-chemical theories and classifications, but in Anatomy, the Hindus went one step further; they practised dissection on dead bodies for purposes of demonstration. Ingenious directions are given, e.g., the body must be first disembowelled and wrapped round with the kusa and other grasses, then kept immersed in still water for seven days, after which the medical student should proceed to remove the layers of the skin with a carefully prepared brush made of the fresh elastic fibres of green bamboos;—which will enable the tissues, vessels and ducts to be observed. Post-mortem operations as well as major operations in obstetric surgery (the extraction of the foetus, etc.) were availed of for embryological observations (e.g., it is stated as a result of observation that the rudiments of the head and the limbs begin to appear in the foetus in the third month, and are developed in the fourth; the bones, ligaments, nails, hair, etc. becoming distinct in the sixth);—and also embryological theories, e.g., the indication of sexual character in the second month by the shape of the foetus, the shape of a round joint indicating the male sex, and an
elongated shape as of a muscle the female sex (cf. Charaka, Sutrasthána, Chap. IV,—हिताय भाषी घनः
ब्रम्हवति विकर पेडङ्गूँः वा । तव घनः पिण्डः पुष्पः स्व वेशी वर्मुहूः
नपुंक्तकम्। Chakrapáni notes : घनः साधनः। पिण्डी तस्मातः।
पेणो धीमाच्येन्द्रावातः। प्रस्यदं वर्ण वीरमवर्मः loc. cit.). In
Phonetics (as in the Prátiśákhya-s, circa 600 B. C.),
in Descriptive and Analytical Grammar (as in Pánini), and in some important respects in Com-
parative Grammar (as in Chanda's and Hema-
chandra's Grammars of the Prákrita Dialects), the
observation was precise, minute and thoroughly
scientific. This was also the case in Materia Medica,
and in Therapeutics, especially the symptomology
of diseases. In Meteorology, the Hindus used the
rain-gauge in their weather forecasts for the year,
made careful observations of the different kinds
of clouds and other atmospheric phenomena
(e. g., they give the heights of the clouds, the dis-
tance from which lightning is ordinarily visible,
or the thunder is heard, the area of disturbance
of different earth-quakes, the height to which
the terrestrial atmosphere extends, etc., vide
Varáhamihira, Srípati, and the authorities quoted by
Utpala). In Astronomy, the observation was;
generally speaking, very defective as in the deter-
mination of the solar and the planetary elements,
and this was probably due to the lack of practical
interest, but the determination of the lunar con-
stants entering into the calculation of lunar periods.