Indian Journal of History of Science, **26** (3), 1991

NEWTON'S PHYSICS IN THE CONTEXT OF HIS WORKS ON CHEMISTRY AND ALCHEMY

PRAJIT K. BASU

Department of Philosophy
The University of Iowa
Iowa City, Iowa 52242
USA

(Received 17 September, 1990)

In this paper, it has been argued that Newton's work in physics can be better understood in the context of his works on chemistry and alchemy. First, Newton's work on alchemy and chemistry is located in the context of a few basic philosophical strands. These strands include concepts of matter, motion, causation, and the explanation of phenomenon. Next, how the concept of 'force' becomes a part of Newton's ontology and plays an important role in explanation, relegating the concept of substance to a less important role, is traced. It is also shown that Newton's scientific work needs to be and can be fruitfully understood from the perspectives of his metaphysical commitment to non-Humean causation, to corpuscularianism and to epistemology. Furthermore, it is argued that Newton's *Principia* and the *Opticks* point to his invoking of 'active principles' which act as causal agents. In fact the notion of substance and of the substantial reality of concepts like 'force' or laws of force led Newton to 'active principles'. The notions of explanation, metaphysics of causation, and ontology interacted strongly to shape Newton's philosophical and scientific thoughts. Also, the tension between questions about 'how' and 'why' a phenomenon occurs plays an important role in the above interaction.

In this short appraisal, first a few basic philosophical strands, which are important for understanding Newton's work in alchemy, will be discussed. These strands are very general in nature and provide a status of different philosophical notions just before or around Newton's time i.e. the period from middle of sixteenth century to the beginning of eighteenth century. These strands include philosophical views on the concepts of motion, causation, and, explanation of phenomenon and matter. These basic strands will provide a background which may help understand Newton's work better. Given this perspective how the concept of force becomes a part of Newton's ontology and plays an important role in explanation, relegating the concept of substance to less important role than it had in previous physics, is traced. In this process, first a summary of Newton's work in alchemy, as understood by four different scholars, is offered. Next a historical survey of Newtons's work in the contexts of the basic strands mentioned above is provided. The metaphysical and epistemological impetus for his work would be pointed out and it will be argued that it is in these contexts that Newton's alchemical work make more sense. Finally, it will be argued that the role of 'why' questions leads Newton to alchemy and that there are both tensions as well as deep rooted similarities in some respects, if viewed in terms of a concern with the metaphysics of causation,

between his alchemical work and the philosophy of *Principia*, the latter being essentially corpuscularian in nature.

The Important Basic Strands

(a) The problem of understanding motion, especially local motion, underwent change from the high and late medieval period to the sixteenth century. In the late medieval period, scholars conceived motion as a kind of process. They understood and described local motion as a progressive actualization of the potentialities of a body towards the goal or the final end of the body in motion. Koyre,[1] and especially Murdoch[2], have pointed out that scholars in the late medieval period formulated the question of local motion as two subquestions: (i) what is the initial cause of any motion? and (ii) what is the cause of keeping a body in motion?. It was the answer to the second question that created a lot of controversy. The explanation of projectile motion was a crucial problem of that time. It was only by invoking 'impetus', a concept far removed from scholastic thinking that the problem was solved by Buridan and others.[3] This concept broke the old was of thinking that the mover and the moved must be in contact through the duration of motion. It paved the way for conceiving local motion of a body as a state (status?) of the body and it was Galileo's pioneering work which led to such a characterization. Galileo construed local motion of a body as a state of a body, this state being independent of other parameters e.g. colour, shape, or the nature of the constituents that make the body and so on. It should be realized that only in a Galilean formulation was the concept of local motion absolutely unrelated to the concept of matter or substance. This dichotomy between matter and motion raises some interesting questions and will be discussed later.

(b) It should be clear from above that the questions of the constitutents of a body and the issue of its local motion are entirely different questions which do not seem to have any connection. However, according to McMullin[4], as well as Hall[5], both Galileo and Bacon not only made some vague distinctions between primary and secondary qualities of bodies but even hinted at the possibility of explaining the latter qualities by mechanism and mechanics. This clearly implies that both Galileo and Bacon were trying to explain some qualities of substances or bodies in terms of the motion of these bodies. From them through Descartes, Boyle, Hobbes and finally Newton, similar idea was gaining ground. It will not be necessary to go into the details of the primary-secondary distinction of qualities, since McMullin's article offers a very clear idea of what was involved in the late sixteenth and seventeenth centuries.[6] Thus according to McMullin, in the seventeenth century

> ....'matter' came to be defined as the bearer of the 'primary' properties. To be 'material' was to possess these properties and thus fall within the scope of mechanical description and explanation. .....the suggestion was that there were certain quantitative characteristics common to all physical objects, and these had to be accepted as the necessary and sufficient basis for mechanics. .....matter becomes by definition exactly correlative with mechanics; mechanics is directed to the understanding of matter as matter, and matter is that which can be exactly comprehended by the methods of mechanics.[7]

(c) It should be clear from this that the concepts of matter and machanics were inextricably linked in the seventeenth century. And that is the most crucial philosophical idea of that time. Otherwise, there is somewhat vague notions of primary and secondary qualities and even of 'forces' in the late medieval period in the context of the theory of matter. According to Weisheipl[8], Meier[9], and McMullin[10] there were two distinct schools of thought in the late medieval period. The first school took any substance as a composite of matter and form, while the second school held any substance to be a compound of four elements i.e. air, water, fire and earth. These two views were reconciled in some way but that generated problems of its own. From the perspective of the first school, the four elements were constituents of matter. From the perspective of the second school, these four were ultimate components of matter. The reconciled notion was that there was a universal material substrate which was informed with substantial forms. A composite had a form compounded out of the elemental forms, while the element had only the elemental form. There was a search for a set of elemental qualities. There was also a kind of distinction between primary (active) and secondary (inactive) qualities distinction, with the latter being dependent upon the former. The problem of change in matter was solved by positing forces which were thought to be celestial in nature.

(d) The important distinction between metaphysical thinking of the late medieval period and that of the seventeenth century is that in the former period the predominant idea is the mataphysics of substance while in the latter period it is the metaphysics of quality. This difference. had its ramifications felt in the understanding of causation, in explanation of phenomena, and so on. It must be mentioned, however, that these changes took place over centuries.

One of the important concepts is that of causation. It appears that the concept took a new meaning from the time of Galileo in the field of physics. Moody[11] has pointed out that Galileo, following the Oxford Mertonians, was trying to answer the question 'how' a phenomenon occurred instead of 'why' a phenomenon occurred. Buchdahl[12] also makes similar point about the works of Descartes and Newton. Thus, according to Buchdahl, Descartes was in favour of rejecting the notion of 'final cause'. Descartes insisted in the *Problems of Philosophy* that we must

> ...attempt solely to discover, through the faculty of reasoning ..., *how* the things which we perceive by means of our senses could have been produced.[13]

In the context of gravity, Buchdahl[14] claims, Newton attempted to answer the question 'how' and arrived at the mathematical equations for gravitation.

It was pointed out in the previous sub-sections that in the seventeenth century, matter, primary and secondary qualities of matter, change i.e. transformation and transmutation of matter were thought to be explainable by invoking local motion of bodies. In the medieval period the notion of 'substance' accounted for the explanation of phenomena. It was the chief principle. In the seventeenth century, the metaphysics of qualities provided redescriptions of phenomena. The qualities themselves did not provide any explanation of phenomena. Matter was understood as particles; the

qualities, and the local motion of these particles together provided a contained references to qualities or motion which were or could be rendered meaningful by giving an operational definition. This allowed quantification of variables but at the same time led to sharpening of the definition of the terms or concepts used. The operational definition also made it possible to quantify certain variables, a step very crucial in the growth of seventeenth century mechanics and science of motion. Thus any proposition about nature was made meaningful by the reference of its terms to qualities of motions of bodies or equations of motion of bodies.

(e) Closely associated with the above was notion of explanation which underwent significant changes from the time of Aristotle to that of Newton. In the Aristotelian sense, an explanation of any proposition was complete when the subject term had been correctly classified under the genus and species of the predicate term.

In the seventeenth century or late sixteenth century, the concept of explanation changed. The corpuscularian nature of matter and motions of such corpuscles formed the basis of explanation of phenomena as it was hinted in the last sub-section. The characterization of phenomena was in terms of matter i.e. particles, some primary or active qualities and the local motion of the particles. Newton's work will be discussed in this context. However, it was also during this period, that another important change was going on. As mentioned in the last sub-section, concept of substance lost its pivotal role in metaphysics. Instead, substance was replaced by the function it performed. As Cassirer[15] and Buchdahl[16] have shown with series of facts and analyses, the role of substance becomes less important in understanding the phenomena of the world. To explain 'X is red' or the equation of motion 'v = gt' one need not bring in the notion of substance or substratum or first or second principle much like the scholastics. The equation of motion did not even invoke any concept of substance to describe local motion of a body in free fall. It should be apparent then that the laws of motion or laws of nature play a major role in explaining. The second law of motion as propounded by Newton did contain a term which is related to a notion of body. This term 'mass' should be understood, however, as only an operationally defined concept, and had no other ontological ground. If this is granted, any kind of motion or forces leading to such motions could be involved for explanation of phenomena of nature, and yet there would be larking suspicion if repeatability of such motions had no 'substantialized' or any other ontological grounding to express the necessitarian nature reflecting the possibility of repeated application. It was in this context the laws of motion or laws of force seemed to provide such a 'substantiality' to motions, a kind of physical reality which was lacking when the concept of substance was rendered useless. Newton's work will be discussed also from this perspectitive.

There is an interesting aspect in Newton's work which seem to reflect a tension between the last two forms of explanations of phenomena. This tension resulted because Newton at least, wanted to ask the question 'why' and tried to give an answer to such questions. In *Principia*, Newton explained the phenomena of motion using a set of laws for local motion as well as gravitation and 'force'. In the *Optics*, Newton invoked corpuscularianism and, curiously enough, some 'active principles' to explain the properties of light. In his alchemical studies, Newton first invoked

corpuscularianism and 'forces'. But at a later stage, he invoked 'active principles' and 'forces' to provide the necessary explanatory concepts. Newton also thought that there were general laws of motion in alchemy, which could be discovered. It is plausible to think that in order to provide a 'substantial reality' to the laws of force, 'force', gravition, action-at-a-distance, Newton invoked 'active principles'. It is also plausible that Newton asked 'why' it is that 'forces' act the way they do and also what was the cause for action-at-a-distance etc. and that he invoked 'active principles' to account for the causal power. His alchemical work, therefore, was a search for 'active principles'.

A Summary of a Comparative Study of Newton's Work on Alchemy

In this section, a very brief descriptions of the four different views of Newton's alchemical work as discussed by Westfall[17], Rattansi[18], McGuire[19] and Dobbs[20] are discussed. In this process certain major features of Newton's alchemical work would be discussed as well as important similarities and differences among these author's views and analysis would be pointed out. The presentation and understanding of Newton's alchemical work in this section will provide a perspective for a major analysis of the work, undertaken in the later sections of this article. The differences in the different authors' main theses as discussed here may be seen to provide a starting point for the later analysis. Westfall's view is discussed first simply because it is more interesting philosophically and Dobbs' view is discussed last because it provides us a synthesis of different views.

Westfall claims that Newton's philosophy of nature may be understood as a product of a meaningful interaction between mechanical philosophy and Newton's alchemical philosophy. According to Westfall, Newton actually incorporated the Hermetic concept of 'active principles' into his mechanical philosophy in a most important way, allowing the modification of orthodox mechanism and subsequently allowing it to rise above itself to the more sophisticated level of modern science. Westfall takes the Hermetic tradition to be made up of three closely related aspects of a conception of nature: (1) nature was seen as active as opposed to passive and inert; individual bodies have their own sources of activity, 'active principles', whereby they set themselves in operation and perform their specific acts; (2) nature was seen as active and animate so that no meaningful distinction could be drawn between animate and inanimate; (3) nature was seen as psychic; the characteristic actions of bodies were understood in terms of mental categories; bodies exercise influence on each other in terms of sympathies and antipathies. Thus according to Westfall

> In Newton, peculiarly Hermetic notions fostered the crucial development of his scientific thought, and in concept of force became a central element both in the enduring science of mechanics and in the accepted idea of nature. ....The fundamental question is the mutual interaction of the two traditions in the development of Newton's thought.[21]

Westfall goes on to claim of Newton,

> Moreover, his habit of referring to forces as 'active principles' suggests a greater influence of Renaissance Naturalism than he readily would have acknowledged.[22]

According to Rattansi, Newton's works and assumptions imply some sort of a dialectic between new (i.e. seventeenth century) inductively and experimentally based knowledge and the ancient texts. In a letter to Oldenberg in 1675, Newton[23] mentioned three speculations which had a striking resemblance to the alchemical texts he was studying. These were: (1) the creation of all things from aether by condensation combined with the idea of a particular spirit within that aether which was contained within the pores of matter as a principle of activity 'for the continual use of nature'; (2) the continual condensation of that particular spirit by the earth, while the exchange of 'as such matter' sent out in an aerial form from the bowels of the earth sets up a circulation; (3) the existence of 'sociability' and 'unsociability' between various substances through a 'secret principle' and action of intermediaries in resolving it. According to Rattansi, Newton equated alchemical *spiritus* with a quasi-cartesian aether. Newton made a sharp distinction between vegetation and mechanical action. Rattansi also suggests that the relation between Newton's alchemical studies and his 'official' science becomes clearer if the assumption guiding two other sorts of studies, which absorbed a great deal of his attention, is examined carefully. These are his Biblical studies, especially of the prophetic books of the Bible; and the second, his studies of ancient natural philosophy. Underlying both sorts of studies was the assumption that truth was anciently given. The idea of a *prisca sapientia* helped to legitimize Hermetical magical work and to remove the tinge of atheism from atomism.

McGuire summarizes the thesis of Neoplatonism as held by the Camdridge Neoplatonists of Newton's time, as follows:

> Since passive matter is categorically devoid of principles of change, it can be activated causally only by principles extrinsic to its nature, vital and animated agents. ..... passive nature has to be continually replenished by causal intermediaries actually existing in direct subordination to divine omnipresence.[24]

McGuire claims that Newton was influenced only by Neoplationism and not by Hermeticism. He takes Newton to believe in nature as containing an active and a passive principle. Newton also seemed to consider various sorts of active agents both material and immaterial. McGuire also claims that Newton invoked 'active principles' to explain the cause of 'forces'.

Dobb's pioneering work on the early period of Newton's alchemy can be summarized as follows:

(1) Newton might have begun studying transmutation with Boylean concepts.

(2) He then shifted to alchemical processes.

(3) He claimed that he came up with 'philosophic mercury'.

(4) There were three crucial alchemical concepts behind the programme which gave rise to 'Clavis' or Key: (a) Neoplatonic 'universal spirit' or spirituous 'aire', the source of all specific forms of matter; (b) the concept of

'Mediation', the 'middle nature' required for the joining of disparate substances; (c) the concept of 'active principles' exemplified in the process, by the attraction of the 'antimonial magnet' and by the 'fermental virtue' drawn in by the magnet.

(5) He conceived the Neoplatonic 'universal spirit' as a particulate mechanical system and the 'Mediation' as particles of intermediate size. The original concept of aether failing to stand further experimental testing, he adopted a new concept of force which incorporated the alchemical 'active principle' into mechanism.

In the next two sections, it will be argued that the Westfall- Dobbs view is essentially correct though McGuire's claim that 'active principles' play a causal, role in the explanation of forces may have some plausibility. The scope of this paper excludes any discussion of Newton's theological commitments and roles of such commitments in his metaphysical thinking especially in his ontology.

A Historical Survey of Newton's Work

According to Dobbs, Newton was at first a plenist. In his student notebook of 1661-65, Newton tried to explain the phenomenon of gravity by the pressure of a descending aether shower. The question that he left unaddressed was what made aether move. Newton also tried to explain the cohesion of bodies from the plenist point of view but later he doubted such an explanation. it should be kept in mind that at that time the problem of cohesion of material particles was not dealt with satisfactorily by corpuscularian philosophy. The problem of cohesion in living bodies was more serious and not even a tentative explanation in terms of material particles was available. For the inert bodies, there was only an *ad hoc* explanation — by invoking hooks and springs attached to the particles — from the corpuscularians of that time. These three questions or problems and solutions to these had a great impact and many ramifications in Newton's thoughts and will be discussed later. Newton's theory of matter was similar to that of the atomists of his time. He thought that there were small particles which form large particles by virtue of some kind of attractive power of force but he did not explain what this 'force' was. In short, force was not yet a part of his metaphysics of being.

In 1669, Newton prepared a short paper containing a series of alchemical propositions. According to Dobbs, Newton was in the process of modifying his mechanical philosophy. This short paper did not deemphasize the unity of matter or corpuscularianism. However, it introduced a new substance called 'magnesia'. This 'magnesia' much like other materials come from the 'same roots' implying 'magnesia' was generically the same as other materials so far as the basic nature of the fundamental constituents were concerned. Yet, it had a special property i.e. it revivified. What was Newton trying to achieve in that paper? According to Dobbs, Newton

> had become preoccupied with a process of disorganization and reorganization by which developed species of matter might be radically reduced, revivified and led to generate new forms. The alchemical agent responsible for these changes is vitalistic and universal in actions; it is a 'fermental virtue' or 'vegetable spirit'.[25]

In the same tract among the propositions, Newton claimed,

> This and only this (magnesia) is the vital agent through all things that exist in the world. And it is the mercurial spirit, most subtle and wholly volatile, dispersed through all places. This agent has the same general method of operating in all things, namely excited to actions by a moderate heat, it is put to a flight by a great one, and once an aggregate has been formed, the agents first actions is to putrefy the aggregate and confound it into chaos. Then it proceeds to generation.[26]

What is of importance here is that Newton's ontology has been modified or is in the process of change. Instead of allowing only particles which were inert, he incorporated at least one element which was 'active' and not inert. The crucial reason for adopting such an ontology was the need to explain certain phenomena like cohesion of living beings, putrefaction etc. This should be evident from the above quotations. There are two questions which remain unanswered. The first is why Newton thought that cohesion in living beings can not be explained by particle mechanics. One tentative answer is, of course, his readings in alchemical texts and his theological commitments, which ultimately made him believe in hierarchies of beings in nature. The second question is why he invoked an element which had 'active' power? His new element 'magnesia' is truly a surprising one. It comes from the 'same root' as any other material. Yet it has 'active' properties. How does such an element have those 'active' properties? The element could not have had such a property being generated out of the 'same root' unless there was some rearrangement of the unit material. If so, then the activity is explainable by mechanism. Newton remained silent regarding how and why only 'magnesia' had some interesting properties and what were the nature of those properties or active power. It is one thing to explain some phenomena in an *ad hoc* fashion by ascribing some properties and quite anothr to attribute such properties to any element. Thus, Newton's invoking of a new element was in the line of his corpuscularianism while ascribing a peculiar property of 'activity' to that element was most probably in influence from his readings of alchemical texts. This reflects the peculiar nature of his ontology if not at least that it is a tension-ridden one.

In 1674 or around that time, Newton wrote a treatise named *De Aere et Aethere*[27]. This treatise represents his metaphysics of being as well as his epistemic commitment, in terms of sense-data, of that period. While he tried to explain properties of air as e.g. rarefaction and condensation, using particles and motion, he employed the concept of 'force' in his explanation. For example, he tried to explain compression of air, especially Hooke's experiments, saying that if the particles of air were in mutual contact, we could not provide any explanation.

> But if by some principle acting at a distance [the particles] tend to recede mutually from each other, reason persuades us that when the distance between their centers is doubled, the *force* of recession will be halved, when trebled the *force* is reduced to a third and so on and thus by an easy computation it is discovered that the expansion of air is reciprocal to the compressive *force*.[28]

Concerning the generation and nature of air Newton's view was that:

> ... the atmosphere is composed of many kind of air, which nevertheless can be divided into three chief kinds: vapours, which arise from thicker and more fixed substances, especially in the vegetable kingdom, one of a middle nature; and air

> properly so called whose permanence and gravity are indications that it is nothing else than a collection of metallic particles which subterranean corrosions daily disperse from each other, This is confirmed by the fact that this latter air serves neither for the presentation of fire nor for the use of animals in breathing, as do serve some of the exhalations arising from the softer substances of vegetable matter or salts[29].

What is striking is that all the three kinds of air show the properties of condensation and rarefaction and yet these have quite different properties. They have even different constituents. The third type is the only true and permanent air. The other kinds have being only for a shorter duration. The second type of air seems to have properties which help sustain breathing in animals. As in the previous alchemical text Newton remained silent about why only one kind of air has such a vital property while the others do not. So far, there are hints of concepts like 'action-at-a-distance' and 'force' and 'principle' along with 'vital property' in the last two quotations. There is also an indication of his corpuscularianism in his description of third type of air. That his thinking was in a very strongly corpuscularian mode is shown by his comments on the nature of aether or air:

> And just as bodies of this Earth by breaking into small particles are converted into air, so these particles can be broken into lesser ones by some violent action and converted into more subtle air which if it is subtle enough to penetrate the pores of glass, crystal and other terrestrial bodies, we may call the spirit of air or aether[30].

It should be clear by now Newton's ontology is clearly mechanical, though it is not free of problems. That 'force' intrudes in his explanation of condensation of air through the concept of action-at-a-distance, committing him to occult (?) qualities, cannot be doubted. And the reason why only one specific kind of air is fit for breathing for living beings remains not only unexplained but even unaddressed.

What were Newton's epistemological commitments? It will be examined later in more detail that he commits himself to sense-data. However, explanation of a phenomenon in a hypothetico-deductive sense is also an acceptable epistemological justification. In that sense, it is chiefly inductive.

An example taken from *De Aere et Aethere* would help analyzing Newton's commitments. Newton postulated the existence of aether as a subtle air, a kind of small particles. He thought he had experimental evidence for that:

> That such spirits exist is shown by the experiments of Boyle in which metals fused in a hermetically sealed glass for such a time that part is converted into calx, become heavier. It is also clear that the increase is from a *most subtle saline spirit* which, coming through the pores of the glass, calcines the metal and turns into calx. And that in a glass empty of air a pendulum preserves its oscillatory motion not much longer than in the open air, although that motion ought not to cease unless, when the air is exhausted, there remains in the glass *something much more subtle* which damps the motion of the bob[31].

The first experiment is more straight forward in the sense that the weight of the calx is more than the weight of the metal, implying something must have been added to metal. It is the aether that has been added to the metal, given the condition of the experiment, in which the metal could not have come into contact with anything else. It is the second

experiment which is more interesting, for Newton uses the result of this experiment at a later time to argue that aether does not exist. Newton's argument in favour of existence of aether makes use of the same data from the pendulum experiment. The argument is as follows:

(1) A pendulum stops oscillating in air, because of air resistance, after time t.

(2) The same pendulum stops its oscillation in a glass box devoid of air after time t'. $(t = t')$

(3) But the empty glass box should not provide any resistance.

(4) (2) and (3) imply that there is some resistance.

(5) Hence, there must be some subtle material (i.e. aether).

In the above explanation, there is no mention at all of 'why' air or aether provides resistance. It helps to measure resistance in terms of time 't'. And given the observations, it becomes necessary to introduce a 'theoretical entity' like aether for explanation. In some sense this is a case of hypothetico-deductive method that Newton adopted. It should not, however, be forgotten that it was a result of his ontological commitment to the existence of aether. For at a later time he made use of similar observations but explained away absence of aether. He had the following as an argument:

> ... since it is the opinion of some that there is a certain ethereal medium extremely rare and subtile, which free pervades the pores of all bodies; and from such a medium, so pervading the pores of all bodies; and from such a medium, so pervading. The pores of bodies, some resistance must needs arise. .....[From the experiments] the resistance of the empty box in its internal parts will be above 5000 times less than the resistance on its external surface. This reasoning depends upon the supposition that the great resistance of the full box arises not from any other latent cause, but only from the action of some subtile fluid upon the included metal[32].

Newton finally concluded that the resistance 'is either nil or wholly insensible'[33]. And hence, the experimental evidence is against the existence of aether. In these two cases, it appears that his ontological commitment led to different explanations of similar kind of data. This important point, that Newton's ontological commitments play a major role in his work and epistemic justifications play a lesser role, will be substantiated later.

Coming back to Newton's works on alchemy, it may be seen that his alchemical treatises and a treatise like *De Aere et Aethere* reflect a tension in his thinking. He believed in the unity of matter and thought that every substance had the 'same root'. However, he also believed that the 'power' of some substances were qualitatively different from those of other substances. The major thesis of particle mechanics was that every phenomenon, every property of a body, could be explained by the arrangement the particles have and their motions and laws of motion. But such an explanation was incomplete according to Newton. Corpuscularianism could allow that propositions about a phenomenon or properties of a body could be formed. It also

allowed mathematical formulation of laws of motion which had terms that were associated with the state of a system. As a result, it allowed in principle that certain properties of a system be operationally definable and measurable. What the corpuscularianism did not do was to answer 'why' some substances act the way they do, 'why' the laws of motion the way they are. The alchemical views, on the other hand, seemed to indicate 'why' some substances act the way they do. Thus if one asked 'why' something was putrefied, the cause, Newton asserted, was the active power of 'magnesia'. To account for the active power of 'magnesia', he invoked the existence of aether.

Newton went on to explain processes like fermentation, vegetation and cohesion of living bodies by invoking a vital aether. The reflection of this enterprise of explaining various kinds of processes mentioned may be seen in Query 31 of the *Opticks*, published later. In his untitled alchemical treatise, referred to as *Of nature's obvious laws and processes in vegetation* Newton describes this vital aether in terms of its actions in earth. Dobbs' work would be quoted extensively in this context:

> The earth is a 'great animal', he [Newton] says,' or rather an inanimate vegetable [that]draws in aetherall breath for its daily refreshment and vital ferment and transpires again with gross exhalations'. He goes on to describe this 'aethereal breath' as a 'subtle spirit', 'nature's universal agent, her secret fire' and the 'material soul of all matter'.....the subtle aethereal agent is the 'only ferment and principle' of all vegetation[34].

Newton in the above treatise made a distinction between vegetation and mechanism and thus arrived at two levels or kinds of explanations. This leads to similar tension, as before. This tension comes while trying to characterize the active power or vital nature of aether. If Newton believed in the unity of matter, and aether was a subtle matter, then there would be no fundamental difference between the levels. Thus, either the aether was the basis of all kinds of substances, or aether was another kind of substance with interesting properties, or aether was an 'active principle' which could not be grounded, at least not directly, epistemically. That Newton thought that aether was a 'principle' of some sort should be obvious from the quotation. It would be very instructive to look, in somewhat more detail, at Newton's expressed views on this matter in the above treatise. Newton explained:

> 6 There is, therefore, besides the sensible changes wrought in the textures of gross matter, a more subtle, and noble way of working in all vegetables which makes its products distinct from all others; and the immediate seat of these operations is not the whole bulk of the matter, but rather an exceedingly subtle and unimaginably small portion of matter diffused through the mass, which if it were separated, there would remain but a dead and inactive earth. And this appears in that vegetables are deprived of vegetable virtues by any small excess of heat, the tender spirit being either put to flight or at least corrupted thereby, whereas those operations which depend upon the textures of the grosser matter receive no damage by heats far greater.
>
> 7 'Tis the difference therefore of those grosser substances to be medium or vehicle in which rather than upon which those vegetable substances perform their action.

> 8 Yet those grosser substances are very apt to put on various external appearances according to the present state of the invisible invariant, as to appear bones, flesh, wood, fruit etc. Namely, they consisting of differing particles watery, earthy, saline, airy, oily, spirituous etc., those parts may be variously *moved* one among other, according to the acting of the latent vegetable substances and be variously associated and concatenated together by their influence[35].

It thus appears that there are different kinds of substances. One of them is inert and dead, while the other is the essential ingredient to give 'life' to this gross, inert and dead matter. This 'vegetable virtue' can, however, be corrupted. The properties of the grosser bodies which are amenable to senseperception are dependent on the *movement* of the smaller particles, which are earthy, watery etc. This movement, in turn, is affected by the 'acting of the latent vegetable substance'. The 'activity' of this vegetable substance also determines how the small watery, earthy, etc. particles are 'associated and concatenated'. Such an association and concatenation also determine the states and properties of grosser substances. It is not clear from the above passages if these two kinds of substances are really fundamentally different kinds or if they are made up of the same material but have different properties. The first view implies a different kind of ontology from that of the second, the latter being closer to the corpuscularian view of Newton's time. The first implies an ontology which perhaps is the fore-runner of his later ontology, which includes 'force'. It may be seen from the above quotation that, according to Newton, the properties of grosser bodies can be explained by the motion and structure (association and concatenation) of smaller particles of various kinds e.g. watery, earthy etc. This is clearly a corpuscularian explanation. The only difference, if any, from the Boylean kind of corpuscularianism is the assumption of different kinds of small particles e.g. watery, earthy, saline, fiery etc. But that reflects a relatively inelegant ontology compared to those of other versions of corpuscularianisms in which only one kind of particle is invoked. It should also be clear that such an explanation gives an answer 'how' some particles move and associate and concatenate and thus give rise to certain properties. It does not answer 'why' the 'vegetable substance' produce motion or act to bring particles together. It is not necessary that one has to ask such a question, but Newton did. As a result, he had two choices for an answer. Either there is a different kind of substance with active power or there is a different kind of causal agent ('force', 'principle'), which acts as a motive force. However, it must be clarified that it is not possible to decide what Newton actually believed. His treatise *De Aere et Aethere* shows a corpuscularian ontology which is different from the view just described above. And both the treatises were written almost at the same time.

It was mentioned while describing Newton's view in his alchemical treatise *On natural laws etc.* that he made a distinction between vegetation and mechanism. It should then appear reasonable that he also made some kind of distinction between explanations at those two levels. However, it is easy to see the ontological difference between these two realms. One way to resolve this tension is to dissolve the distinction between the two levels of explanation. This may mean either that there are explanations at the mechanical level which can be subsumed under the explanations at the vegetation level or the reverse. This will allow a richer ontology, but not necessarily a more

elegent one. In *De Aere et Aethere* and *On natural laws etc.*, Newton opted for corpuscularian view for explanations. Such explanations gave an answer to 'how' some particles through their motions and associations gave rise to some properties. Though such particles are of different kinds e.g. watery, earthy, etc., Newton could explain away such properties by the motion and association of some 'fundamental' particles, as he seemed to do in *Opticks*. Thus, it could be assumed that he was thinking of only one kind of matter with different kinds of properties, at least as an alternative. This becomes clear in his work *An Hypothesis Explaining the Properties of Light*, published in 1675, in which Newton proposed an aethereal medium. This aethereal medium, much like air but far rarer, subtler and strongly elastic, was supposed to be diffused through the entire universe. This aethere could condense. And in its condensed form it provided the substance of all the bodies of the world. Thus Newton's ontology was simple to the extent that it had only one kind of matter. Also, he pictured the earth as a vast alembic, perpetually distilling its contents into an aetherall spirit which precipitated, only to be distilled again. He explained a range of active phenomena-gravity, electrical and magnetic phenomena, cohesion of bodies, elasticity, heat, sense-perception, muscular motion and vegetable growths. The descent of aether toward the earth, caused by its condensation in fermentations and fires, bore down bodies and caused the phenomenon of gravity. There were some complications, however. The corpuscles of light seemed to have a 'Principle of Motion' and also the 'maine flegmatic body of aether' had diffused through it 'divers aetherall spirits that *cause* sundry phenomena'[36]. The similarity of this situation with that discussed in the last paragraph is important. Corpuscularian explanations answer 'how' the gravitation and electrical phenomena work but not 'why' light has properties like 'Principle of Motion' etc. It should be apparent by now that though Newton wanted a complete explanation of any phenomenon, he did not succeed in giving one. The corpuscularian explanation answered 'how' a phenomenon occurred and such an explanation might be understood as having the form of a hypothetico-deductive explanation, as described in the twentieth century. The explanation that should answer 'why' a phenomenonn occurred has similarity to the 'resolutive method'. The concept of 'resolutive method' of explanation could be traced not only to Galileo but also to the medieval philosophers[37]. In this explanation, one is supposed to start from the observation or data about any phenomenon and trace back to the ultimate causes or ultimate premises, which are supposed to be self-evident. The difference between these two kinds of explanations is reflected in the difference between two metaphysics of causation. The corpuscularian explanation, by itself, is committed to pro-Humean kind of causation while the resolutive explanation is closely not non-Humean. It is not very surprising that Newton who wrote in a time period which was between that of Galileo and that of Hume, felt the influence of both positions. This could also give a clue why Newton could not subsume explanations at the vegetation and mechanical levels into each other. It should also be clear by now that while mechanical explanation answered 'how' a phenomenon occurred, the explanation at the vegetation level answered 'why' a phenomenon occurred.

A discussion of some of Newton's work in chemistry as well as his *Principia* is in order to reveal not only a common thread in his thinking through his chemical works but also some interesting aspects of *Principia* from the perspective of his ontology and metaphysics of causation. Among Newton's chemical works I shall concentrate on *De*

Naturum Acidorum, a treatise written in 1691 or around that time. In this treatise, Newton spelled out his thoughts about hierarchies in matter, the building blocks of chemical substances, the nature of different kinds of substances, transmutation of matter etc. Newton considered 'the largest particles of all substances whatever to be compounded of earthy particles and acid particles in arrangements which varied from one substance to another, and also identified "mercury" and "sulphur" with his earthy and acidic particles'[38]. He tried to explain the vatious chemical properties of all ordinary substances by invoking internal arrangements of earthy and acid particles, an explanation which would be corpuscularian in nature. In other words, it would be an explanation of 'how' a substance had a particular property, rather than any other. This explanation would not be enough for Newton, for it did not answer 'why' a substance had a particular property and not any other property. For example, Newton explained the composition of fatty acids, in the following way:

> If the acid particles are joined with the earthy ones in a lesser proportion they are so closely held by the latter that they are, as it were, suppressed and hidden by them. For they no longer excite the organs of sense, nor do they attract water, but they compose bodies which are sweet and which do not readily mix with water; that is they compose fatty bodies[39].

The above explanation points out 'how' certain properties of acid particles are diminished in intensities by the earthy particles, and thus give rise to the properties of fatty bodies. What the explanation does not do is answer 'why' acid or earthy particles have the properties that they do. Newton, of course, took those particles as bearers of chemical properties but did not explain the origin of such properties by invoking further corpuscularian systems. Interestingly enough, it was held at Newton's time, as well as in earlier periods, that there were 'chymic principles' which acted as bearer of such properties. Newton managed to give a physical grounding to such principles but the mode of explanation changed from 'resolutive' to corpuscularian. Those 'principles' were self-evident to the hermetics and the alchemists, and explanation of chemical properties and phenomena by these 'principles' could thus be envisaged as 'resolutive' when such 'principles' were invoked as efficient, if not final, causes[40]. Newton instead used the concept of force to provide this kind of explanation. It should be clear from above that Newton's works in chemistry also reflect the dichotomy between two ontologies and two metaphysics of causation.

A brief but incisive look at the *Principia*, a paradigm example of Newton's corpuscularian thinking, is in order now. There are some interesting assertions, in this work, which are not very transparent. The notion of 'force' was one of the most elusive concepts which Newton used to set up the dynamics of terrestrial bodies and also to explain the motion of heavenly bodies. I shall discuss this later. In *Principia*, Newton referred only to quantity of matter while referring to bodies. But, he held a general view that 'any body can be transformed into another body of any kind whatsoever, and can assume successively all intermediate degrees of quality'[41]. Much more interestingly, in a draft conclusion for the first edition of *Principia*. he speculated that the difference between natural kinds might be explained in terms of 'particles coalescing in new ways'. Yet not all qualities could undergo such a change, e.g. solidity or inertia could

not, while colour could. He thus introduced a distinction between what he called universal qualities and qualities to be explained by universal qualities. Thus for Newton, there were particles with universal qualities, and these were primary matter. The universal qualities provide a sufficient characterization of matter to explain the entire range of behaviour of physical bodies. The properties or qualities which may be called secondary (in the Lockean sense) are real and can be explained by the universal qualities. But he did not claim that all the properties of bodies could be explained in terms of these universal qualities. He said that with these and a variety of 'forces' all natural phenomena could be explained. So far Newton was a corpuscularian.

The difficulties arose when Newton tried to explicate the notions of 'force' and matter, and wanted to explain what the laws of motion were. In this process he ascribed the cause of 'force' of resistance, to motion of a body in rest, and to its inactivity. He attributed to matter an 'innate force' which he thought was responsible for uniform motion and which had an active role not only in impact but also in motion under central forces. Thus it would appear that primary matter would have such properties as 'force'. But as noted before, 'force' was supposed to be a different kind of entity whose ontological status was not at par with that of primary matter or universal qualities. The epistemological justification for the existence of 'force' was far inferior to that of existence of primary matter with its univeral qualities or secondary qualities. McMullin[42] correctly points out that as a result Newton "focussed rather on laws of motion which were their [forces'] observable effects and in terms of which alone forces could be known". It should be mentioned that obvious explanations of all natural phenomena occur. But 'why' primary matter had motion under the influence of a 'force' or 'why' it had a property like 'force' did not have any answer. There was also no answer to 'why' there would be uniform motion especially in heavenly bodies. The 'resolutive' explanation of the phenomenon of uniform motion seemed to take the explanation back to a level where Newton invoked 'active principles', which were not a quality of bodies and did not inhere in bodies. The 'active principles' seemed to be at a level higher than those of 'forces', for some 'forces' could at least inhere in bodies or be properties of bodies, while 'active principles' caused the phenomena of conservation of motion or that of gravitation. However, there is room for confusion about the status of 'forces' and of 'active principles' as used by Newton in his writings. Yet, it will be pointed out later that he did distinguish between 'forces' and 'active principles', the latter being the cause of the former.

The digression to Newton's work on chemistry and to the *Principia* shows that Newton's alchemical work and writings share ontologically some similarity with that of his *Principia* and chemical works. Two important points stand out. The first is the explanation (close to hypothetico-deductive explanation) of phenomena at the corpuscularian level and thus an ontological commitment to particles. Along with this, there is a commitment to a specific notion of causation which is close to Humean notion of causation. The second is to give a 'resolutive' explanation of phenomena, an answer to 'why' a phenomenon occurs as opposed to 'how' a phenomenon occurs, the latter being provided by the first type of explanation.

The 'resolutive' explanation committed Newton to a non-Humean kind of causation. The search for efficient causes or final causes of phenomena led him to

postulate different entities. First, it was the 'force', an entity for which there was no epistemic justification in the nature of direct empirical evidence. Next,it was 'active principles' which caused or gave rise to 'forces'. The epistemic justification for the 'forces' was at least the laws of force; the 'active principles' did not even have such a justification. Newton recognized the need to find out the laws for these 'principles'. But he had some other kinds of justifications for believing in such 'principles'. It is Westfall's claim that Newton was influenced by Hermetic texts while invoking such principles[43]. McGuire[44], however, claims that it was only the Neoplatonism of More and Cudworth in terms of active and passive 'principles' that influenced Newton. From Dobbs' work, it appears that both the Neoplatonic principles and Hermetic texts influenced Newton's beliefs in such principles and in those of his alchemical works[45]. The above analysis also seems to indicate that the metaphysics of causation, the metaphysics of being and the notion of explanation interact with each other to determine a methodology of science. That Newton believed in 'resolutive' explanation should be clear from the following passage:

> I have hitherto been *arguing from the effects to their causes & carried the argument (as high as) up to certain forces* (the powers) by which little bodies act on one another at small distances[46].

To summarize, how Newton's ontology went through certain changes has been discussed. The analysis also bears out the claim that Newton's view of matter is more corpuscularian in nature and rather different from that of the medieval period in its details, though unity of matter is a common thread linking these concepts. It has also been shown that Newton believed that corpuscles and motions of such corpuscles gave rise to different phenomena, thus taking motion more as a state of a body and in the process explaining properties in terms of motion. It seems quite plausible that Newton also tried to explain phenomena by giving efficient causes and in the process adopted 'resolutive' explanation. The latter kind of explanation could be associated with non-Humean causation while the corpuscularian explanation could be associated with Human causation. The 'resolutive' explanation and non-Humean causation led Newton to invoke entities like 'force' and 'active principles' which enriched Newton's ontology.

Substance, Force and Active Principles

It has been mentioned above that Newton introduced spirits and 'principles' into his ontology to account for causation. His effort to account for phenomena such as vegetation and cohesion on the one hand and explanation of mechanical events on the other led to tensions in, but also enrichment of, his ontology. Finally, he decided to continue with corpuscles of matter in motion and included 'forces' and 'active principles'. A brief look at these three concepts of substance, 'force', and 'active principles' is in order.

The draft A of the *General Scholium* brings out a very clear idea about Newton's conception of substance. For him,

> We do not know the substances of things. We do not have any idea of them. ....We know the properties of things from phenomena, and from the properties we infer that things themselves exist and we call them substances. ....We see but shapes and colours of bodies, we hear but sounds, we touch but external objects, we smell odours and taste flavours; but we know the substances or essences themselves by no sense, by no reflex action;... we nowhere argue about the idea of substances apart from properties[47].

An idea of Newton's conception of change may be seen clearly in the following passage in Query 31 in the *Opticks*:

> While the particles continue entire, they may compose bodies of one and the same nature and texture in all ages; but should they wear away or break in pieces, the nature of things depending upon them would be changed. ....And, ...that nature may be lasting, the changes of corporeal things are to be placed only in the various separations and new associations and motion of those permanent bodies[48].

It seems then, for Newton, the true nature of substances are not known in the epistemic sense. There is no inductive and empirical mode of access to substances in terms of sense-data. The sense-data of properties do not permit any one to legitimately conclude the existence, and define the nature of a substance. It is a surprise then, that for Newton there was no problem of reality for particles with universal qualities. Newton used analogical reasoning to explain such qualities. But he recognized indirect epistemic justification through the ability of explaining phenomena. In hypothetico-deductive sense, Newton gave an indirect epistemic justification. Otherwise, the problems that plague substances plague these particles as well. It must, however, be remembered that only measurable property of substance was, for Newton, quantity of matter in the sense that only quantity of matter had relevance, if at all, with the notion of substance while describing motion.

A detailed discussion of the concept of 'forces' is not offered here, since Westfall's analysis of Newton's conception of 'forces' is both pioneering and illuminating[49], and Newton's concept of 'force' has already been discussed somewhat sketchily in the last section following Westfall's analysis. The only new important feature that needs mentioning is that the matter-measure was correlated with change of motion. Such changes are brought by 'forces', a new mechanical specification of the older notion of efficient cause[50]. It was mentioned in the last section that notion of 'force' was somewhat unclear for Newton used it in at least two different senses viz. property of a body and cause of many kinds of phenomena including chemical phenomena. The origin of this concept, it was argued, depended on Newton's commitment to Hermetic thoughts and more fundamentally to 'resolutive' explanation. It should be pointed out again that Newton offered explanatory power of laws of 'force' as an epistemic evidence for the notion of 'force'.

It was mentioned in the last section that 'active principles' caused 'forces'. What did Newton say about 'active principles' and their roles? Newton said in the *Opticks*.:

> It seems to further, that these Particles have not only *Vis Inertiae*, accompanied with such passive Laws of Motion as naturally result from that Force, But also that they are moved by certain active Principles, such as is that of Gravity, and that which causes

> Fermentation and the Cohesion of Bodies. These Principles, I consider..... as general Laws of Nature, by which the things themselves are form'd: Their Truth appearing to us from Phaenomena.[51]

That the 'active principles' also conserve motion is clear from the following passage:

> Seeing therefore the variety of Motion which we find in the World is always decreasing, there is a necessity of conserving and recruiting it by active Principles, such as are the cause of Gravity by which Planets and Comets keep their Motions in their Orbs, and Bodies acquire great Motion in falling; ..... For we meet with very little Motion in the World, besides what is owing to these active Principles.[52]

Also, these 'active principles' are necessary for putting bodies in motion :

> The *vis inertiae* is a passive principle by which bodies resist as much as they are resisted. By this principle alone there never could have been any motion in the world. Some other principle was necessary for putting bodies in motion, and now that they are in motion, some other principle is necessary for conserving the motion.[53]

Similar assertion is made by Newton again:

> For Bodies (alone considered as long, broad, thick ...) are passive. By their *vis inertiae* they continue in their state of moving or resting & receive motion proportional to ye force impressing it & resist as much as they are resisted; but they can not move themselves; & without some other principle than the *vis inertiae* there could be *no motion* in the world.[54]

It must be pointed out that McMullin thinks the above quotes do not show that 'active principles' cause local motions, i.e. play a role in impact dynamics.[55] McGuire correctly points out that Newton did hold that 'active principles' cause forces of any kind and were part of reality and could be discovered through investigation. A discussion of these two different views and argument for the plausibility of McGuire's thesis now follows.

In the example of Newton's works on chemistry, mentioned before, it was pointed out that Newton attributed certain important properties to earthy and acid particles to explain many chemical phenomena. It appears that certain 'chymic principles' had those properties and these principles were invoked by hermetic scholars to explain chemical phenomena. The status of these 'principles' becomes clear when we read Dobbs' exposition on them:

> Classifications on the basis of secondary characteristics having been made, it was perhaps inevitable that 'chymists' could conceive that certain chemical 'principles' underlay the classes, principles which were themselves abstract substances and were the bearers of the important distinguishing properties of the classes. It may be argued, that the Empedoclean-Aristotelian elements were all just this sort of abstract substances, devised to account for the secondary characteristics of bodies. The elements were 'metaphysical' or 'transcendental' and were themselves unobtainable, but they served as the 'basic substances' which were the carriers of physical and chemical properties.[56]

There are two important points to be noted. The first is the similarity of the primary substance as articulated by Albertus Magnus and Thomas Aquinas to the principles.

This primary substance or principle is abstract substance and hence can act as a subject of any predication in a proposition. One can never know the nature of this primary substance, nor of the substance about which Newton conversed. Instead of the substance we can have some classificatory principles to explain properties of bodies or phenomena. The second important point is the notion of explanation. It is obvious that explanation is achieved by using the classificatory principles, by subsuming a body under a class or species and genus in Aristotelian sense. The principles with their properties were like species and genus or more accurately the properties were like genus and species. In this kind of explanation the substantial reality is proved by the secondary substance, which is an actualization of primary substance, subsumed under the species and genus i.e. categories.

It is this kind of substantial reality that is missing in corpuscularian explanation or when the notion of substance is replaced by its function. In the former, there is an indication of existence of particles with certain universal properties but there are two important problems. The first is the absence of direct inductive and empirical access to the particles. The second is that the universal properties are arrived at from the properties of gross bodies through analogical reasoning. There is a serious problem now if the explanations of the properties of gross bodies employ the universal qualities. Of course, one could have two distinct kinds of properties as Newton proposed but it could be charged that this is an *ad hoc* distinction. The major brunt of explanation would thus have to be borne by 'force', an entity Newton introduced. The problem however, remains about the substantial reality of 'force' and along with it the necessitarian and the prescriptive nature of an explanation, a problem that was of no importance in the first kind of explanation. The problem is more serious when there are propositions or mathematical formulas which do not refer to any property of a body that could be taken as a classificatory property or even the most used quantitative property mass. This loss of substantial reality is made good, according to Buchdahl,

> ...by according a more 'concrete' status to the concept of law as being itself an ultimate introducing at the same time further causal factors; ..... The operative concept in all these was force. But as Newton realized very soon, what was relevant here again was only the law of force.[57]

The laws of force or laws or nature are expressed either as sentences or propositions with subject and predicate or as mathematical formulas in which the terms refer to certain properties of a body or of a state of a body. Using these laws of motion one could deduce in a deductive-nomological sense the properties or phenomena to be explained. The substantial reality of the terms is provided by the necessitarian implication of the word 'law' in law of nature thus ascribing a universal nature and the syntactical (logical) power of such a proposition or mathematical formula.

The important question, however, is whether laws of nature when expressed as propositions or formulas have substantial reality. These laws, through their necessitarian and prescriptive power, give a reality to an explanation of phenomenon or property. However, Newton was not completely satisfied with such an explanation. He wanted these laws of motion or force to be derivable from more general laws. But this

would be possible if there were higher level entities or concepts. Newton was convinced that there were such entities and that those caused 'forces'. These entities were 'active principles'. These 'principles' were to be understood as causes of 'forces' and as the effects of God's will. The only other option was to hold that there was independent evidence for their existence which he could not for there was no inductive evidence for such 'principles' nor was there any logical necessity. However, the alchemical principles in Hermetic texts as well as Neoplatonism and Neoplatonic principles might have provided a gound for the reality of those 'principles'. It would be fair to ask why he did not stop at 'force' and invoked God's will as the cause of 'force'. The answer is perhaps that 'force' acts directly on bodies be it in local motion or gravitation. Being a believer in hierarchy of level of beings, he might have thought that 'force' was too close to a mundane level. Thus 'active principles' act as a medium between God's will and 'forces'.

It may be claimed that 'force' in local motion and that in gravitation are of different natures. The explanation of the latter requires introduction of 'active principles'. It is undoubtedly so. But this is only part of the story. It must be remembered that the notion of 'force' in local motion is not as transparent as it is taken to be by many scholars. Newton had to explain 'why' a body had *vis inertiae* for example. It was necessary for his commitment to 'resolutive' explanation. It might be argued that Newton could have invoked two different kinds of 'forces' and that one kind would be at a higher level in his ontology than the other. The plausibility of such an argument as well as the thesis that 'active principle' had no connection with 'force' in local motion is seriously weakened by the following facts. First is that Newton's three laws were laws of forces. These laws had to have substantial reality. Second, Newton insisted that 'active principles' could be understood and their laws could be known in principle. And all the phenomena of nature could be derived from these laws. It should follow then that the laws of local motion could be derived from those general laws. By virtue of this derivation from the general laws, the laws of local motion would have substantial reality. The 'active principles' Newton even hinted, perhaps caused all the kinds of motion. In seventeenth century, there were held to be three distinct kinds of 'principle'. These were: (a) something formulated or asserted -the primary truths, mathematical propositions, laws of nature falling in this category; (b) the primitive *arche* out of which all things were thought to originate; and (c) the primary cause of existing phenomena.[58] Both the first and the third senses could be found in Newton's conception of principles. The 'active principles' were causal agents. These caused motion through 'forces'. In its turn, these were grounded by the will of God. The 'active principles' were part of his ontology. What is puzzling is that the 'resolutive' explanation stops at the 'active principles'. These 'principles' are thus supposed to be self-evident 'principles' from which any phenomenon could be derived. Yet, the claim that there is a need to know the laws in this realm. So the laws are not self-evident. If that is so, then the knowledge of these laws is a prerequisite to gain a full causal explanation of the phenomenon. God is the final cause and not the efficient cause of a phenomenon. Recourse to God will make 'active principles' self-evident only derivatively.

To summarize, Newton's notion of substance, 'force', laws of force and 'active principles' provide an understanding how he tried to explain phenomena and in the

process was forced to incorporate various kinds of 'principles' and entities. The pressure was both metaphysical and logical. His metaphysical commitment to some kind of 'substance' led him to believe incorpuscularianism. And yet when he formulated the laws of motion there was not even any mention of 'substance'. This loss of substantial reality was recovered when the laws of motion were subsequently derived from more general laws giving the derived laws a reality and certainty based on syntactical or logical necessity. Alongside, there was the answer to 'how' a phenomenon occurs in contrast to an answer to 'why' a phenomenon occurs. In Aristotelian kinds of explanation there was no distinction between 'why' and 'how' a phenomenon occurs. But a shift from Aristotelian explanation to corpuscularianism which reflected a considerable loss of substantial reality and a different metaphysics of causation led to Newton's invoking of entities like 'force' and 'active principles' and in his choice of the latter, both the Hermetic texts and Neoplatonism played a crucial and important role.

Conclusion

In this paper, Newton's work on alchemy from the perspectives of his metaphysical commitment to non-Humean causation, his commitment to corpuscularianism and his epistemology has been discussed. Four different views on Newton's alchemy have been summarized. Next, the alchemical work done by Newton until 1675 was employed to show tensions in his ontology. It has also been pointed out how his work of 1675 as well as the most celebrated works *Principia* and the *Opticks* invoke 'active principles'. It has been argued that the notion of explanation, the metaphysics of causation, and ontology interacted strongly to shape Newton's philosophical and scientific thoughts. The roles of questions, i.e. 'how' a phenomenon occurs and 'why' a phenomenon occurs, play an important role in the above interaction. Finally, the notion of substance and substantial reality of 'force' or laws of force led Newton to posit 'active principles' and then to the complex conceptual web of laws of motion, substance, 'force' and 'active principles'. Studies of Newton's alchemical works should help in clarifying the structure of the complex web and thereby illuminate Newton's methodology of science.

Acknowledgement

I would like to thank Professors E. Fales, K.H.Tachau, and M.G.Ash of the University of Iowa, and Professor S.G. Kulkarni of the University of Hyderabad for going through the draft and making invaluable suggestions.

References

[1]Koyre', A., *Metaphysics and Measurement*', Chapman and Hall, Cambridge, Massachusetts, 1968, pp. 1-16.

[2]Murdoch, J. and Sylla, E.D., "The Science of Motion", in, *Science in the Middle Ages*, ed., D.C.Lindberg, The University of Chicago Press, Chicago, 1978, pp. 206-64.

[3]For Buridan's philosophy of motion, see Murdoch *et al*, "Motion", p. 212.

Jean Buridan treated impetus as a qualtiy inherent in a mobile, proportional both to the mass of the mobile and to its velocity. For him, impetus was a quasi-permanent quality. He claimed that once the mobile was set

in motion, it would tend to continue to move under the action of the impetus until some counteracting cause were employed. Impetus, for him, was not a self-expending quality. This notion need not be confused with the notion of inertia. Ontologically, there is at least the following difference. Impetus, as Buridan understood it, was the cause for the continuing of motion. Inertia, as we understand it, is a force needed to *change* the motion (or rest) of a body. The *Nyāya-Vaiśeṣika* analyses of impetus are many. I think some of the modern commentators have glossed over this concept and treated it as a synonym for inertia (*vega*), velocity, or even speed. *Vaiśeṣikas* (at least some of them) hold that impetus of a body loses its forces as it expends energy and thus the body eventually slows down and stops. This view is close to the modern day energy concept. Some *Naiyāyikas* hold that impetus (or inertia?) is momentary and produces another one at the next moment. The differences between the concept of impetus that Buridan employed and the *Nyāya-Vaiśeṣika* schools held are apparently many. Karl Potter argues that inertia was assumed to be a specific quality of a body by some schools. But there were other schools which rejected such a characterization. More interestingly, some philosophers in these schools have tried to reduce inertia to motion, while others have argued that motion is not produced by inertia. If we do take impetus as a synonym for inertia, then the differences with the concept of impetus that Buridan employs stands out. First, Buridan construed it as a quasi-permanent quality. Also, he employed it to explain the continuation of motion in a projectile, not to reduce it to motion or to argue that motion is produced by inertia. The *Nyāya-Vaiśeṣika* concepts of impetus require a very careful and sympathetic analysis.

[4]McMullin, E., Introduction, in, *The Concept of Matter in Modern Philosophy*, ed., E. McMullin, University of Notre Dame Press, Notre Dame, 1978 a, pp. 1-55.

[5]Hall, M.B., Matter in Seventeenth Century Science, in, *The Concept of Matter in Modern Philosophy*, ed., E. McMullin, University of Notre Dame Press, Notre Dame, 1978, p. 80.

[6]McMullin, "Matter, Modern", pp. 1-55.

[7]McMullin, "Matter, Modern", p. 35.

[8]Weisheipl, J.A., O.P., "The Concept of Matter in Fourteenth Century Science", in, *The Concept of Matter in Greek and Medieval Philosophy*, ed., E.McMullin, University of Notre Dame Press, Notre Dame, 1965, pp. 147-69.

[9]Meier, A., "The Theory of the Elements and the Problem of their Participation", in, *On the Threshold of Exact Science*, ed., S. Sargent, University of Pennsylvania Press, Philadelphia, 1982, pp.124-42.

[10]McMullin, E., Matter as a Principle, in, *The Concept of Matter in Greek and Medieval Philosophy*, ed.E.McMullin, University of Notre Dame Press, Notre Dame, 1965, pp, 173-212.

[11]Moody, E.A., Galileo and Avempace, The Dynamics of the Learning Tower Experiment II, *Journal of the History of Ideas* (1951), *12*, 375-422.

[12]Buchdahl, G., "Explanation and Gravity", in *Changing Perspectives in the History of Science*, eds., R. M. Young and M. Teich, Heinemann, London, 1973, pp. 167-204.

[13]Descartes, R., *Oeuvres de Descartes*, eds., C. Adams and P. Tannery, Paris, 1897, vol. IX, p. 37.

[14]Buchdahl, "Explanation", p. 196.

[15]Cassirer, E.*Substance and Function & Einstein's Theory of Relativity*, Dover, New York, 1953, pp. 139-51.

[16]Buchdahl, G., *Metaphysics and the Philosophy of Science*, The MIT Press, Cambridge, Massachusetts, 1969, pp. 51-9.

[17]Westfall, R. S., "Newton and Alchemy", in, *Occult and Scientific Mentalities in the Renaissance*. ed., B. Vickers, Cambridge University Press, Cambridge, 1984, pp. 315-35.

[18]Rattansi, P. M., "Newton's Alchemical Studies", in, *Science, Medicine and Society in the Renaissance*, ed.,A.G. Debus, Science History Publications, New York, 1972, pp. 167-82.

[19]McGuire, J.E. Neoplatonism and Active Principles; Newton and the Corpus Hermeticum, in R.S.Westman and J.E. McGuire, *Hermeticism and the Scientific Revolution*, William Andrews Clark Memorial library, University of California Press, Los Angeles, 1977, pp. 95-142.

[20]Dobbs, B. J. T., *The Foundation of Newton's Alchemy*. Cambridge University Press, Cambridge, 1975.

[21]Westfall, R.S., "Newton and the Hermetic Tradition", in, *Science, Medicine and Society in the Renaissance*, ed., A.G. Debus, Science History Publications, New York, 1972, p. 185.

[22]Westfall, R.S., *Force in Newton's Physics*, Macdonald, London, 1971. p.388.

[23]Newton's Letter to Oldenberg in 1675; see Dobbs, "Foundations", pp. 204-5.

[24]McGuire, "Neoplatonism", p. 99.

[25]Dobbs, B.J.T., "Newton's Alchemy and His Theory of Matter", *Isis* (1982). *73*, 511-528. (See especially pp. 514-5)

[26]Dobbs, "Matter", p. 515.
[27]Newton, I., *Unpublished Scientific Papers of Isaac Newton*, eds., A. R. Hall and M. B. Hall, Cambridge University Press, Cambridge, 1962, pp.221-8.
[28]Newton, "Unpublished", pp. 223-4.
[29]Newton, "Unpublished", 1962, p.227.
[30]*Ibid.*
[31]Newton, "Unpublished", pp. 227-8.
[32]Newton, I., *Isaac Newton's Philosophiae Naturalis Principia Mathematica*' Third Edition, Two Vols., eds., A. Koyre' and I. B. Cohen, Cambridge University Press, Cambridge, 1972, p. 463.
[33]*Ibid.*
[34]Dobbs, "Matter", p. 517.
[35]Dobbs, "Matter", p. 518.
[36]Westfall, "Hermetic", p. 189.
[37]Galileo, G., *On Motion and On Mechanics*, Tr., S. Drake and I. E. Drabkin, The University of Wisconsin Press, Madison, 1960, p. 88.
[38]Dobbs, "Foundations", p. 221.
[39]*Ibid.*
[40]Wallace, W. A., *Galileo and His Sources*, Princeton University Press, 1984, pp. 99-101.
[41]Newton, I., *Philosophiae Naturalis Principia Mathematica*, Third Edition, Tr., A. Motte and rev. F. Cajori, University of California Press, Berkeley, 1934, Bk.III, Prop.6, Hypothesis 3.
[42]McMullin, E., *Newton on Matter and Activity*, University of Notre Dame Press, Notre Dame, 1978 b, p. 46.
[43]Westfall, R. S., "The Role of Alchemy in Newton's Career", in, *Reason, Experiment* and *Mysticism*, eds., M. L. Righini-Bonelli and W. Shea, Science History Publications, New York, 1975, pp. 189-232.
[44]McGuire, J. E., Force, Active Principles and Newton's Invisible Realms, *Ambix* (1968), *15*, 154-208.
[45]Dobbs,"Foundations", pp. 194-232.
[46]See in McGuire, "Active Principles", p. 170.
[47]Newton, "Unpublished", pp. 340-1.
[48]Newton, I., *Opticks*, Fourth Edition, Reprinted, New York, 1952, pp. 400-1.
[49]Westfall, "Force", pp. 323-423.
[50]*ibid.*
[51]Newton, I., *Opticks*, 1717-18, p. 375,
[52]Newton, "*Opticks* (1952)", p. 399.
[53]Newton, "*Opticks* (1952)" p. 397.
[54]See in McGuire, "Active Principles", pp. 170-1.
[55]McMullin, "Activity", p. 82.
[56]Dobbs, "Foundations", p. 135.
[57]Buchdahl, "Metaphysics", p. 52,
[58]McGuire, "Active Principles", p. 194.