Logic and chemistry in Hegel's philosophy

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Abstract: Hegel's *chef-d'œuvre*, the *Science of Logic*, contains a section on 'measure'. As 'measure' unites the two categories 'quality' and 'quantity', it is a key aspect for determining qualitative and quantitative objects, and hence is the decisive category for natural sciences. In the chemical passages of this section, Hegel took concepts from chemistry (for example 'elective attraction'), changed their function, and converted them into categories of logic. In this paper, the relationship between the development of categories by reflecting reason and the chemical material cited for this development is discussed. Hegel claimed that the chemical material presupposed in the logical development could be replaced with specified proportions of measures, derived from developing and specifying the category 'measure'. This claim is criticized.

Keywords: *Hegel, logical development, measure, chemical concepts, logic and its material.*

1. Introduction

In the early 19th century, Hegel faced the emergence of the science of chemistry. Chemistry revolutionized its central theorems and produced sensational discoveries in a bafflingly short period, but could not achieve clarification of its fundamental principles. In a systematic way, Hegel tried to conceive the highly topical knowledge of chemical phenomena and incorporated the result of this reflection into a key passage of his *Science of Logic*, the section about "measure"[1]. There he developed the categories of 'quality' and 'quantity' into new categories, *viz.* those of 'measure'. He claimed the latter to be fundamental for the philosophy of natural sciences. In the course of this, Hegel not only used examples from contemporary science for didactic illustrations in order to grasp more easily the structure of a category, but he also took concepts from chemistry and physics ('elective attraction', 'nodal line'), changed their function, and converted them into categories of logic. These categories, 'new' as compared to the classical concepts of logic, are the coordinating links for the movement from the categories of 'being' ('quality',

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'quantity', and 'measure') to those of 'essence' ('identity', 'difference', 'contradiction', 'ground').

Although fundamental, this movement remained obscure. On the one hand, natural scientists considered Hegel's *Philosophy of Nature* to be hocus-pocus, drastically contradicted by the progress in chemistry and physics, and discredited all passages of Hegel's *Science of Logic* in which models from the *Philosophy of Nature* played a role. On the other hand, philosophers tried to keep the *Science of Logic* independent of every specific material that had become obsolete by scientific progress. However, taking logic as a realm of pure thought (*i.e.* thinking about only pure thinking) makes the idea of a development of logical concepts impossible. Hegel himself considered the passage where he develops logical concepts *with regard to* chemical and physical concepts as one of the most difficult topics.[2]

2. From Kant to Hegel

Hegel's construction of concepts is comprehensible only if we recall Kant's explanation of transcendental principles of pure reason[3] and of metaphysical principles of natural sciences.[4] Kant distinguished[5] between "cognition by pure reason gained only from concepts" [*reine Vernunfterkenntniß aus bloßen Begriffen*], which results from immanent reflection of reason upon its pure concepts of understanding and which he called "pure philosophy or metaphysics", and "cognition by reason gained from the constructing of concepts" [*Vernunfterkenntniß durch Construction der Begriffe*], which he called "mathematical cognition by reason" [*mathematische Vernunfterkenntniß*]. Since construction cannot be performed without anything, a material is required that Kant found in 'pure intuition'. Starting from "mathematical cognition by reason", cognition of nature by reason – according to Kant the "pure part of all real natural science"[6] – can be obtained if the "existence of something" and, more specific, the "concept of matter at all" is taken as the basis for construction.[7] Only by means of this concept, possible relations in mathematics can be restricted to those relevant to physics. It was already Kant's idea to develop principles apodictically valid for every natural science. The reflection of reason upon itself enables synthetic judgements a priori, "but only discursively, by concepts".[8] It does not remain in itself, but becomes reason constructing in the "pure intuitions of space and time", where constructing is limited by something third, the presupposed and heterogeneous material of construction. Kant's claim on this is inconsistent: His "concept of matter at all" does not require particular empirical knowledge; however, it is "empirical in itself", separated from "particular experiences".[9] Because of the key function of "construction of concepts" [*Construction der*

Begriffe], there is, according to Kant, only so much real science in each physical theory, as mathematics is found in it.[10]

Hegel's "development of measure" is a consequent continuation as well as a critique of Kant's plan to construct the principles for natural sciences a priori. Kant's "mathematical cognition by reason", which is constructing concepts in 'pure intuition', is treated by Hegel as the development of the category 'quantity' in the section Quantity of the *Science of Logic*. The limitation of "mathematical cognition by reason" to apodictic principles of the natural sciences is elaborated on in the section Measure. To that end, "mathematical cognition by reason" is constitutive in a double manner; first, as the basis and starting point for the development of the category 'measure'; secondly, as the form of "constructing" in the "development of measure", *viz.* as the "quantitative ratio",[11] according the following steps. One measure is set into relations to other measures; these relations of measures yield distinct proportions (ratios) of measures; these proportions (ratios) can be determined by an 'exponent'; 'exponents' on their part are measures, they are set into relations to others which yield once more proportions of measures *etc.*

According to Kant, the categories are given and fixed, and as such they are presupposed for the "complete analysis of the concept of matter at all".[12] They are alien to the constructing activity, but required. Hegel criticized Kant's representation of the categories in that Kant picked them up "empirically",[13] *viz.* out of a "subjective logic", by gathering given forms of judgement and deriving thereof his (pure) concepts of understanding (categories). Such an empirical access to the categories is contradictory to their function in a transcendental logic, however. Accordingly, Kant did not conceive the "necessity" of the categories. "He does not think about setting the unity and deducing out of the unity the differences" and therefore he did not think about "deducing" the categories.[14]

Hegel systematized the categories (or, more precisely, the titles for the four classes of the categories 'quality', 'quantity', 'relation', 'modality'), which, according to Kant, are alien to each other as well as to the constructing activity, by developing them as merging into one another. Thus, the "development of measure" emerges out of 'quality' and 'quantity' and is their unity. This was Hegel's response to Kant's *Metaphysical Foundations of Natural Science*. He further developed the categories that are more concrete, such as 'real measure', 'measure as series of proportions of measures', 'elective affinity', 'nodal line of proportions of measures' in the section Measure. These are the building blocks for a theory of the fundamental principles of natural sciences. The key for understanding Hegel's critique of Kant's "construction of concepts" lies in Hegel's material for the "development of measure", for it replaces Kant's "concept of matter at all" as the limiting basis for the constructing of concepts in 'pure intuition'.

3. The material for the work of determining and developing concepts

In order to discuss the relation between reason, which reflects upon its concepts and develops them by construction, and the material being whatsoever, we must first examine the assumption that there is no such relation. According to this view, we cannot start with the given existence of a specifically determined material and from given categories by which that material can alone be conceived. The only 'thing' given and presupposed would be, as Hegel himself said, "being, pure being, – without any further determination".[15] Thus, the *Science of Logic* would be an immanent reflection upon that "pure being". This immanent reflection is not to be understood in the subjective-idealistic version, *i.e.* as the immanent reflection of reason reflecting by means of the principles 'unity', 'diversity', and 'affinity' upon the categories given in the forms of judgement. But it is yet precisely the immanent reflection to which nothing else is given but an object at all – as indefinite as possible – *viz.* "pure being". The "development of measure" would be the immanent reflection upon what arises from the beginning, the absolute denial of determination, which alone can be presupposed, *i.e.* the immanent reflection upon the 'unity' of 'quality' and 'quantity'. Prima facie, it seems to be like that: One measure is set into relation to other measures; from the (distinct) ratio of two measures an 'exponent' of this ratio can be inferred which in turn is a measure; 'exponents' for their part are set into relation, and so ratios of ratios of measures are formed; from those new ratios in turn further 'exponents' can be inferred *etc.* If one follows this deceptive idea, the "development of measure" would be a permutation of the categories 'quality' and 'quantity', performed by reflecting reason by means of its own categories of reflection (the concepts of the 'determinations of reflection', *i.e.* 'identity', 'difference', 'contradiction' *etc.*). However, such a movement of reflecting reason could not be distinguished from the "movement from nothing to nothing, and through that back to itself".[16] For there cannot be made a distinction between the first movement, which takes place in "pure being" and therefore in complete indifference, and the second one which does not make this presupposition and which is a only movement of the 'determinations of reflections'. Thus, the logic of 'being' would coincide with the logic of 'essence'.

However, Hegel denied such a consequence. Therefore, one must conclude that his determining and developing of the abstract beginning toward more and more concrete concepts (in the *Doctrine of Being*) refers to a presupposed material. (It is doubtful whether Hegel himself was always clear about that point or not. In the *Doctrine of Being*, he tried to reduce the presupposition of a distinct and specific material to the presupposition that science has an object at all of whatever specification.) It is only because a (spe-

cific) material restricts reflecting reason,[17] that the process of determining and developing, qua productive imagination and/or qua experimental work acquiring and reshaping the material, is a synthesizing process. In other words, the reflection upon the categories ('quality', 'quantity', 'unity', 'measure', 'negation', and 'relation') and upon their combinations would run idle if it would not refer to a material, each time specifically determined and diverse. Therefore, the key for understanding the logic of 'being' and especially the logic of 'measure' lies in the relation between a specific material and the categorical reflection.

As the *Doctrine of Being* begins with a completely indeterminate object, precisely with 'pure being' or 'pure indeterminateness', the material for the categorical reflection must be added as a specifically determined material and, thus, must be presupposed. Then, when further developed, determinations of measure are set as a substitute for those presuppositions. For that reason, models from physics and chemistry are quoted in the section Measure; chemical concepts like 'neutrality' or 'affinity' become essential for conceiving a science of logic; 'elective affinity' and the physical concept 'nodal line' become logical categories in and through the synthesizing process of the development of 'measure'.

In Kant's "construction of concepts", judgements synthesized a priori are possible only because the construction is performed in 'pure intuition' and, accordingly, has received as its material the 'pure manifold' (*i.e.* the 'pure diversity') which is included in the 'pure intuition'. Kant's argumentation provokes the questions if this 'pure manifold' is an inconsistent concept and if such a 'pure manifold', when removed from every qualified determination, can be material at all. As compared to Kant's basis for the "construction of concepts", his 'pure manifold', Hegel's substratum for 'developing categories' is more concrete.

4. Reason reflecting upon its categories needs chemical material

In the following, the relation between the reason that reflects upon and develops categories and the material for this reflection will be brought out in an example, the 'chemical' passages of the *Science of Logic* in the section on 'measure'. Since 'measure' unites the two categories 'quality' and 'quantity', it is a key aspect for determining qualitative and quantitative objects and therefore the decisive category for natural sciences. The category 'measure', resulting from a movement of reflecting reason, corresponds – as all categories in the *Doctrine of Being* – to a process of and between real things, *viz.* the

process of measuring. Something can only be measured if the thing to be measured is related to a rule.[18]

If both sides of that relation are not of the same quality, then – as the next stage[19] in the development of measuring – a new and more concrete type of 'measure' emerges: the ratio of two quantifiable qualities, one of which is taken as the unit (denominator) and the other one as counting (numerator). For instance, if the two qualities are time and space, velocity is the emerging measure. But as time and space are 'abstract' features, their ratio is external to the thing itself. In order to perform a more genuine measurement, it is necessary to go on to a new measure in which the quality in the numerator is a core quality (mass) compared with that in the denominator (volume). The resulting ratio (density) is a measure that specifies what a thing is. (In Hegel's time, scientists tried to understand the differences in the quality [of substances] as a function of their density.) As compared with the more superficial velocity, density is a quality that constitutes the thing's reality. Hegel called it "real measure".[20]

Yet it is doubtful if the transition to the "real" and allegedly more intrinsic measure can be regarded as a step in the logic of measuring without referring to a particular material. It is also doubtful if there is a merely logical reason that the direct ratio of mass and volume is the correct one for such a measuring. Anyway, chemical substances can be determined and characterized by their "real measure" 'density'. However, this measure is different from the substratum (the chemical substance) to which it refers and which must be given first of all. A substance cannot be completely characterized (i.e. identified) only by its density. Characterization requires density values of several substances to be compared. Moreover, in such a comparison, the substances remain external to each other, to the effect that characterization by external comparison turns out to be superficial. For example, change of external conditions, such as temperature and pressure, can change the values of the superficial quality 'density'.

Thus, the next stage[21] in the logic of measuring can be attained when the substances are no longer external to each other. This is the case if a real process happens in which the substances themselves are involved; first of all, they are mixed. The resulting combination of two measures turns out to be not simply the arithmetical mean, calculable from the individual density values. Instead, the new measure for the combination requires a new measurement. Through the combination of two substances, the movement is performed from an external comparison to a distinct and fixed relation between two measures – generating a new ratio of two measures that, in turn, are ratios of measures. The value of the new ratio characterizes the combination. It is different from the arithmetical mean that would be an 'abstract' measure external to the combination. From that difference, Hegel concludes that there must be a process in which the substances change, and that the quality

of a substance can be characterized more precisely by comparing its initial density with the densities of its combinations with other substances.

Again, it is doubtful if the transition to the combination of real measures (a ratio of ratios of measures) is an inherent development in the logic of measuring.[22] Reference to a real process is necessary. Hegel – as well as contemporary chemists – had difficulties to distinguish between processes in nature. In those times, alloys, solutions, and chemical compounds were frequently confused. At the stage that deals with the combination of 'real measures', Hegel quotes solutions and alloys. In the following stage,[23] "measure as a series of proportions of measures", he quotes chemical compounds. The change of those quoted examples indicates a change of the material to which the (logical) development of 'measure' refers. Moreover, each stage of the development is comprehensible only with regard to its particular material and each transition from one stage to the next one necessarily requires – as Hegel's own sophisticated arguments show – a change of the material quoted.[24] Therefore, we can conclude that Hegel's (logical) development of 'measure' is not self-subsistent and self-sustaining – as his idealistic program demands.

At the already mentioned next stage,[23] Hegel develops the category "self-subsistent real measure" by setting one measure "in relation" to several other measures. This yields "a series of proportions of measures" all being definite, distinct, and fixed. The basis for setting those measures "in relation", *i.e.* reason's material for developing categories, is real processes: the involvement and chemical reactions of substances characterized by "self-subsistent real measures" (*i.e.* by densities). The resulting 'series of proportions of measures' are the series of stoichiometric masses. For example, since one unit mass of sulphuric acid can be neutralized by a specific mass of each of a series of bases, the series of neutralizing masses characterizes sulphuric acid and is called "neutralization series". Analogously, we can determine a "neutralization series" for the same unit mass of another acid, *e.g.* nitric acid. In these two "neutralization series", the values for each base are different, but their ratios are the same. By standardization we can get a specific value for every acid with regard to the standardized "neutralization series". In chemistry, this new measure is called equivalent weight. It characterizes a substance more specifically, more 'chemically' (if the comparative is accepted) and more intrinsically than density. Hegel called it "*Fürsich-bestimmtseyn des Maaßes*" [the measure's being-determined-for-itself] and pointed out that it is an intensive magnitude and that it is more concrete in determining the presupposed substance. In the further development, it replaces the preceding measure (density).

Hegel maintained that a transition in the development of measure can be achieved in strictly logical terms and that the quoted material (here, chemical processes) is arbitrary to the development of categories. However, there are

remarkable shifts within the quoted material.[25] At the first stage, densities are compared while the substances remain unchanged. Secondly, substances are amalgamated and the density of the resulting alloy is compared with the initial densities. Finally, substances react with each other, especially acids and bases in neutralization reactions, and this yields proportions of the stoichiometric masses (not the densities). Only if we refer to the chemical content, the logical transition is comprehensible as well as conclusive; if we do not, the transition is a mystery.[26] By assimilating the just discovered laws of constant and multiple proportions, Hegel directly contradicted Kant who disputed chemistry to be a science.[27]

In order to proceed to the next stage[28] in developing the category 'measure', the particular measures obtained in the previous stage (*i.e.* the equivalent weights) are related to each other. For this logical operation, certain chemical reactions (neutralization reactions of acids and bases) serve as material. The material penetrates the logical development to such an extent that chemical concepts emerge – actually not merely as examples, but rather as content substantial for the logical development that would otherwise run idle. In the neutralization product (the salt), acid and base are in a distinct and fixed proportion, more precisely: the ratio of the stoichiometric masses is constant. The resulting salt has the chemical property that it can be dissolved by certain acids to form corresponding salts and that it excludes the dissolution by other acids which remain inactive. Contemporary chemists suggested an 'elective attraction' that should act between acids and bases if they form a compound. If an acid (A_2) can dissolve a salt (A_1B_1) by replacing the salt's acid to form a new salt (A_2B_1), then the 'elective attraction' between A_2 and B_1 should be stronger than that between A_1 and B_1. The 'elective attraction' should characterize a compound.

In Hegel's categorical construction of the *Science of Logic,* the step from the neutralization reaction to the 'elective' quality of the neutralization product is formulated as the transition from '*Fürsich-bestimmtseyn des Maaßes*' (which he called an 'exponent' of the proportions of previous measures) to 'elective affinity'. He borrowed that concept from contemporary chemistry and used it unchanged as a logical category of 'measure'. If, according to Hegel, those 'exponents' enter into a fixed proportion, they are "negatively set" in it.[29] Through this (negatively setting of the 'exponents'), something underlying for that proportion is set which, first of all, is determined merely negatively against the previous measures (*viz.*, it is not the presupposed 'quality' from the beginning, nor 'quantity', nor 'immediate measure', nor 'exponent' of a proportion of measures, nor a variable 'relation' of such 'exponents'). Nevertheless, it should be the substratum for the proportions of measures and the "truth"[30] of the previous determinations. This construction, and particularly the crucial point of the construction, becomes comprehensible and conclusive through the relation to the material. The

transition, allegedly performed by reflection on the category 'measure', can be deciphered as the transition from the equivalent weight, which results from ratios of stoichiometric masses, to the chemical affinity that is measured today by a quantity of energy such as the free enthalpy (Gibbs energy). Hegel wanted to explain the constancy of the stoichiometric masses of the salt's components by a new measure that describes the chemical property according to which the formation of other salts are excluded. This new measure (*i.e.* chemical affinity) should be developed from the previous measure (equivalent weight) as its underlying basis. Hegel would say that determining a substance – all the way from volume, weight, specific weight, and equivalent weight to elective affinity – means measuring more concretely and thus gradually getting a better understanding of its essence. His efforts at explanation were in accordance with those of contemporary chemists who empirically searched for a relation between the numbers for a 'series of neutralization' (equivalent masses) and the 'elective affinity'.[31]

Today, we know that the driving force of chemical reactions, indicated by a quantity of the measure 'Gibbs energy', is not connected – following a set pattern – with the proportion of the stoichiometric masses of the reacting substances. We also know that – in Hegelian terms – the constant proportion of 'exponents' and 'elective affinity' are 'external' to each other and that, therefore, 'elective affinity' cannot be developed from the previous proportion of measures. Hegel was aware that the new measure (chemical affinity) is qualitatively different from the previous measure (equivalent weight). However, he was not willing to acknowledge that this difference is a substantial one in the underlying basis, *i.e.* in the material for the determination of 'measure'. The proportions of stoichiometric masses of the reacting substances belong to stoichiometry, whereas Gibbs energies belong to thermodynamics that is different and not derivable from stoichiometry. The substantial difference could have been inferred from the fact that, in the development of 'measure', mere reflection upon the previous determination of 'measure' (the stoichiometric mass proportions) cannot create the new quality. The impossibility indicates that the material distinctiveness does not completely resolve into those (logical) determinations of measure. However, that would be in conflict with Hegel's general program to replace the presupposed material distinctiveness by those determinations of 'measure', developed in the process of reflecting upon the category 'measure'.

Hegel definitely saw the difference between stoichiometric mass proportions and thermodynamic quantities of energy. However, the difference appears in the *Science of Logic* not as a substantial one but in the relation between what he calls the quantitative and the qualitative "side"[32] of 'elective affinity'; or, more precisely, in that both "sides" together do not yield a consistent determination of 'elective affinity'. The "quantitative side" is the value of the measure from the stoichiometric proportions of neutralizing amounts

and is interpreted as quantitative affinity or power of affinity. Being a continuous function, this cannot explain the specific quality of 'elective affinity', the specifically excluding reaction that is a discontinuous function. The explanation, and that is the aim of Hegel's argumentation, should be provided by the turn from continuous change of quantitative proportions of measures to a new quality, performed on the "nodal line", *i.e.* the next stage in the development of 'measure'.[33]

The inconsistency of quantified affinity and qualitatively excluding reaction blows up the determination of the measure 'elective affinity'. This indicates a substantial difference between – in modern terms – quantities of mass and quantities of energy. In Hegelian terms, the inconsistency reflects the difference between the presupposed material distinctiveness and the development of 'measure' by reason reflecting upon its categories. The latter difference becomes, according to Hegel, part of the development of 'measure' itself and is then, in the further development, both cancelled and saved (*i.e.* '*aufgehoben*' [sublated]) by being raised to a reflected form. The crux of idealism lies in this 'transformation'.

Hegel takes the inconsistency as the starting point for his further argumentation: if the relation between quantitative affinity and qualitatively excluding reaction cannot be resolved for a single elective affinity (in a quasi-static manner), then reflecting reason must go on to processes where elective affinities interact with each other. In these processes, the inconsistency should be determinable and resolvable into the relation between continuously changeable and discontinuous quantities of measure. The development of the category 'elective affinity' into 'nodal line of proportions of measures' – the next step in Hegel's derivation[33] – should happen in processes where elective affinities interact with each other, to be represented by proportions of their measures. For these proportions, again, other chemical reactions, *viz.* the reactions of salts with each other, are the material basis. According to Hegel's categorical construction, one elective affinity "is continuing itself"[34] into other elective affinities. This process of continuing can be expressed by a quantitative, continuous run-through of proportions of measures. From this run-through, Hegel infers something qualitative that is required as its basis. The transition to this qualitative basis is the next step of the logical development of 'measure'. Hegel calls it "nodal line" and suggest that this 'measure' must have a producer, *viz.* the "self-specifying unity [...] which produces within itself proportions of measures".[35] The new measure is no longer – as the determinations of 'measure' before – a proportion of "self-subsistent real measures" (such as density, equivalent weight, elective affinity) and, thus, does not refer to a qualitative variety of substances to be presupposed. But it is a whole of process and substratum, of reflexivity and quantitative externality. It is a reflexive unity which, in a process of self-specification, sets proportions of measures and alternates between those

which remain only quantitatively different and those which form specific measures by which the presupposed qualities are completely determinable and in which they resolve themselves.[36]

5. Hegel's work with the material

Neither the categories ('quality', 'quantity', 'unity', 'measure', 'negation', 'relation') by themselves nor reflection upon them and their combinations yield a process which can claim to be a 'development of measure'. In order to develop categories synthetically, reference to a specific material is necessary because only with this material we can ascertain measures and proportions of measures. Natural scientists do not work with an arbitrary, undefined muddle but with identified substances under standardized experimental conditions. They first need to establish a field of objects before proportions of measures (the logical term for laws of nature) can be applied.

Hegel knew that. However, in his view, a defined field of objects only serves to provide some quotable objects such that the examples (taken from different fields) can be used as models for logical developing. These models then play the role of examples, apparently arbitrarily called into play and replaceable with others that might be more suitable for the purpose of illustration (*demonstratio*). Indeed, Hegel replaced his models in the progress of his argument: solutions/alloys with chemical compounds, and neutralization reactions with the reactions of salts with each other. Thus, the particular features ('quality') of a model (and of the corresponding object) are regarded irrelevant to his logical development. Moreover, Hegel applied concepts from a certain discipline that are defined for its field of objects without further ado to other fields; *e.g.* the chemical concept 'elective affinity' to sounds and their relations in acoustics, the physical concept 'nodal line' to chemical reactions of salts and their 'elective attraction'.

Since the synthetic development requires the relation between reason reflecting upon categories, on the one hand, and a specific material, on the other, and since this material, as the replacement of the models shows, is regarded interchangeable, Hegel presupposed a common analogy between the corresponding objects of these models. When certain features of the objects do not fit the common analogy, he either explained this due to the still insufficiently developed state of the science[37] or declared the features as unapproachable by reflecting reason and relegated them to "the particular areas of concrete natural science".[38] The assertion of an analogy, including the distinction in what respects the models (and the corresponding objects) are analogous to each other and in what not, cannot lie in the material itself but only in the categorical reflection. This, however, would be in conflict with Hegel's

understanding that the synthetic development requires a relation to the material. Supposing that such an analogy exists, every material would be equally suitable for the subject of logical development because of the same logos, and one could keep to the model once chosen. Why then do we need to make a special selection among the models; why that juggling – really like a virtuoso – with the models, if they are interchangeable?

Hegel noticed that the development of 'measure' requires determined, qualified objects and that, for each step of the development, different objects are necessary. His artistic composition of the models in quotes, which are crossed over with and merged into one another, should ensure a development of categories that is self-subsistent and self-sustaining with regard to the material as well as referring to the material. However, the artistic handling of quotes has no corresponding basis in the material denoted by those quotes. Thus, Hegel's postulated transition from equivalent weight to chemical affinity could not be confirmed by modern knowledge. A Hegelian could respond by claiming that Hegel chose but an inappropriate example due to the insufficient knowledge of his time. But then we would require better examples because the content of his text cannot be presented without material examples.

Two possibilities are open: If Hegel's artistic handling of quotes is not related to the material denoted by the quotes, a moment of subjective arbitrariness would govern the access to the material.[39] If, on the other hand, such an 'artistic' work with the material proves to be essential for the text, then this would contradict his general program of Objective Idealism.

6. What is the impetus for the logical development?

It is a cardinal problem, to be resolved in the *Science of Logic*, if and how the logical transitions are well-founded. The transition from 'elective affinity' to 'nodal line of proportions of measures' may serve as example. The starting point is the determination of 'elective affinity'. 'Neutrality' is specified as 'elective affinity' by the measure 'power of affinity', which Hegel took from the previous proportions of measures (*i.e.* of equivalent weights). That specification contains a contradiction. The specifying agent, a quantitatively changeable measure, and the basis for the specification, 'neutrality' (determined merely as the negative unity of the measures which form 'elective affinity'), are both 'external' to each other, i.e. they are incompatible with each other. Therefore that specification cannot achieve – what it should – the explanation of the specifically excluding quality of 'elective affinity'.[40] In Hegel's text, this appears as an inconsistency of the relation between the quantitative and the qualitative "side" of 'elective affinity'. Reflecting reason could

recognize this inconsistency as an indication of a preceding, determined quality of the material, *viz.* that stoichiometric proportions of the amounts of the initial substances and Gibbs energy of the compound are physical quantities not reducible to each other.

According to Hegel, the impetus for logical development is a contradiction brought out by reason and, then, reflected by reason. Because reason does not accept such a contradiction, it does not come to a standstill. Here, the determination of 'elective affinity' – 'neutrality' is specified as the specifically excluding 'elective affinity' by the (continuously changing) measure 'power of affinity' – contradicts itself. By reflecting this contradiction, reason turns this contradiction and, through that, the relation between the principle of specification and the basis of specification into *its* object. Thus, reflecting reason must move on to the process of specification in which the contradiction is resolved. This process manifests itself in the relations which individual and diverse 'elective affinities' form with each other. Such 'elective affinities' are measures; their relations can be expressed by distinct proportions of measures. In order to determine such relations as proportions of measures, there must be a substratum that is the underlying basis for these relations. The substratum for these relations emerges in the model cited, *i.e.* the chemical reactions of salts with each other. The logical transition to the 'nodal line' is therefore a process developed out of a contradiction and driven by reason reflecting this contradiction. In order not to remain at a standstill by merely asserting the statement of a contradiction, reason requires reference to particular material. Only with that material quoted, relations of those measures (the 'elective affinities') are determinable, and proportions of measures are defined. In the quote essential to the transition from 'elective afinity' to 'nodal lines of proportions of measures', Hegel used an equivocation in the concept 'neutrality' that was not yet cleared up before years after Hegel's death: First, 'neutrality' is the one salt; afterwards, 'neutrality' is the state in which reactions of salts occur. This is an example of how the models that are used for the different stages of the logical development merge.

7. Idealistic dialectics?

In Hegel's 'development of measure', 'immediate qualities' are replaced with measures, proportions of measures, relations of such proportions, 'exponents' for such relations, *etc.* This is not completely wrong. It reflects the progress of knowledge in the natural sciences. At the beginning, chemical substances were characterized by immediate properties such as gloss, fusibility, and volatility without change. From these three properties, chemists went over to their unity which was determined as the 'basic substance' of

metals, 'mercurius'. 'Mercurius' was no longer an 'immediate quality', but a general principle of metals and related to the moon, the feminine *etc.* Later, such 'immediate qualities' and their uniting 'principles' were replaced with measures – such as density, melting point, relative atomic mass – by a process of scientific development including reflection, critique of the 'principles', and experimental work with substances and their controlled reactions. These measures can form proportions that are partly determined by laws. There can be no objection to such a development of more and more specific measures and to the replacement of former and out-dated 'qualities'. In Hegel's terms, this is the progress from 'immediate quality' to 'immediate measure', to 'real measure', to proportions of such measures, to relations of such proportions, to their 'exponents', *etc.*

There can also be no objection to the findings that the continuous change of proportions of measures is connected with the discontinuous change of qualities.[41] Every specified measure (and thus the specific constellation of continuous and discontinuous change of measures on the 'nodal line') includes qualitative moments. These moments enable reflection upon the qualitative presuppositions of the measure, by which its qualitative basis – a material substratum – can be inferred. The specified proportions of measures fit this material substratum. However, the substratum does not completely dissolve into these proportions of measures, because there are qualitatively diverse substances and basic measures, such as mass, energy, *etc.*, that are not reducible to each other.

Hegel's idealistic program of developing categories does not acknowledge any substantial difference of the substrata. The *Science of Logic* contains two ways of reasoning: first, inference to the basis ('ground') by (metaphorically speaking) going backwards; secondly, self-specifying of 'measure' and, through that, developing more concrete categories – metaphorically speaking, going forwards. Hegel merged both ways; they are set identical. Thereby, the basis ('ground') is set as the result of the development of 'measure'. Thus, Hegel claimed that the qualitative moments included in 'measure' could be completely determined by the system of 'proportions of measure'. From that he concluded that the presupposed qualities could be *dissolved in and replaced with* specified proportions of measures, arising from a process of self-specifying of 'measure'. Ultimately, this claim summarizes what idealistic dialectics argues in respect to the relation between chemistry and philosophy.

How can we formulate a critique of idealistic dialectics?[42] First, by disclosing that idealistic dialectics fails and why it fails, *viz.* because of its inconsistent relation to the material. By so doing (*cf.* the previous sections) we find out something about the material that otherwise, without reference to the idealistic construction, could not be conceived. Secondly, by formulating two theses in opposition to the idealistic construction:

A. Proportions of measures are not a complete substitution for qualities.

Relations between measures exist, as defined relations, only for particular connections of nature. Usually, these connections can be approached only by experimental work that isolates them from the universal connection of nature. Such concrete work refers to a material that is presupposed, determined in itself, and specific. If the dissection of particular connections of nature is an essential condition for every knowledge in the natural sciences and if this condition cannot be eliminated in the progress of knowledge (because the universal connection of nature cannot be completely composed as sum total out of all the particular connections of nature ever dissected), then we can draw the following conclusion. The 'development of measure' which expresses the results of gaining knowledge in terms of proportions of proportions of measures cannot both cancel and save (*i.e.* '*aufheben*' [sublate]) the specific qualities, determined in itself and given with the universal connection of nature.

B. Measures are measures referring to a substratum.

The specific qualities of the substratum are replaced with measures, relations of measures, their proportions, and rules about the proportions of proportions of measures (*i.e.* laws of nature). Hegel tried to conceive such a determination of measure by the development of 'measure'. More precisely, reflecting reason first develops the category 'measure' from the categories 'quality' and 'quantity' and then develops the thus obtained and expounded 'measure' further into the 'nodal line'. This reflection upon the category 'measure' cannot be separated from the development of the category itself. It refers to the relation between measure and substratum, which thus becomes the material of this reflection. Hegel determined the relation between reflecting reason, which develops more and more categories of 'measure', and the material for this developing in such a way that the latter is considered replaceable, merely quoted and merging into one another, finally set by the movement of reflection. This is wrong. *The (specific) material is constitutive for the development of 'measure' into 'essence' and is not to be set (aside) as void, looking from the perspective of the result*. It is simply pretense to think that the development could succeed only by quoting material and that the material would be used up with the result (the general principle of the 'nodal line' or, then, the 'essence') and that, by this procedure, its function for the development of 'measure' into 'essence' would be fulfilled. The pretense that such a movement, detaching itself from material, could succeed is common both to Objective Idealism and (modern) Systems Theory.[43]

Notes

[1] Hegel 1832, pp. 323 ff.

[2] Hegel 1832, p. 327, ll. 18 f.

[3] Kant 1787, B 189 ff.

[4] Kant 1786.

[5] Kant 1786, p. 469; 1787, B 741 ff.

[6] Kant 1786, p. 469.

[7] Kant 1786, p. 472.

[8] Kant 1787, B 748.

[9] Kant 1786, p. 472.

[10] Kant 1786, p. 470.

[11] Hegel 1832, p. 310 ff.

[12] Kant 1786, p. 472.

[13] Hegel 1816, p. 44, l. 5.

[14] Hegel 1833, p. 568.

[15] Hegel 1832, p. 68, l. 19.

[16] Hegel 1813, p. 250, l. 3.

[17] Restriction of reflecting reason by a material means limitation. 'Limitation' is the third category under the title 'quality' after 'reality' and 'negation'. If we follow Hegel and understand this third category as emerging from the first and second one as their unity, we are confronted with the following problem: Limitation of reflecting reason makes possible the development of categories as a synthesizing process. However, the question remains if such limitation is constructable merely by 'distinct negation' without relation to a specifically qualified material.

[18] Hegel 1832, p. 333.

[19] Hegel 1832, pp. 336 ff.

[20] Hegel 1832, pp. 345 ff.

[21] Hegel 1832, p. 347.

[22] Hegel gives the impression that the logic of the developing of 'measure' should be independent of special natural processes. In his *exposition de texte*, Burbidge supports this view; *cf.* Burbidge 1996, pp. 31, 222.

[23] Hegel 1832, pp. 348 ff.

[24] Burbidge (1996, p. 34) argues that the "same quality" is measured, only in "a more sophisticated way". However, in alloys the densities of the components are the measures to be compared, whereas in chemical compounds the stoichiometric masses of the reacting substances are the measures to be set in relation. If natural scientists develop new methods of measuring, they do not erase the specific material. On the contrary, more sophisticated methods can only be found with respect to the resistance of diverse materials. Burbidge suggests that the developing of such methods would be a refinement which proceeds by reflection upon the inherent weakness of the former methods. The specific material and the experimental work with this material would be of a second order (pp. 224 f.).

[25] Burbidge (1996, p. 38) concedes that there is a replacement among the material quoted, and he maintains "that this move cannot be represented, only conceived.

For thought must work through the limitations […] only thought is plastic enough to undergo such metamorphosis". However, it is questionable how this 'plastic' thought could find something beyond the representation that the diverse materials would have in common if their associating thread is actually beyond themselves. It is also questionable why thought should be 'plastic' if it acts beyond the representation of the material for which that plasticity is needed.

[26] Therefore, this passage remained *terra incognita* for 150 years. Philosophers kept the *Science of Logic*, especially those passages of the *Doctrine of Being,* independent from the referring material and, by that, mystified what they thought to be the realm of pure thought.

[27] Kant maintains in the *Metaphysical Foundations of Natural Science*: "As long as there is still no concept found for the chemical actions of substances on each other that can be constructed, *i.e.* no law of approaching or removing of their parts can be given by which – for instance, in proportion to their densities and things like that – those movements together with their effects can be visualized a priori in space and can be represented (a demand which will hardly ever be carried out), so long can chemistry become nothing more than a systematic craft or a doctrine of experimenting, but never a real science, because its principles are merely empirical and allow no a priori representation in intuition" (Kant 1786, pp. 470 f.). To develop the "chemical actions of the substances on one another" out of the proportions of "densities" is just what Hegel tried.

[28] Hegel 1832, pp. 352 ff.

[29] Hegel 1832, p. 351, l. 25.

[30] Cf. Hegel 1813, p. 241, l. 8.

[31] Cf. Ruschig 1997, pp. 128 ff; Kopp 1844, pp. 312 ff.

[32] Hegel 1832, p. 353, ll. 30 ff.

[33] Hegel 1832, pp. 364 ff.

[34] Hegel 1832, p. 364, ll. 10 f.

[35] Hegel 1832, p. 364, l. 29.

[36] In this essay it cannot be clarified if Hegel's construction in the chapter 'nodal line of proportions of measures' is correct. For further considerations, *cf.* Burbidge 1996, pp. 44 ff.; Ruschig 1997, pp. 189 ff.

[37] References: Hegel 1832, p. 362, ll. 32-3; 1813, p. 214, ll. 31-35; 1832, p. 363, ll. 4-6; *cf.* Ruschig 1997, p. 184.

[38] Hegel 1832, p. 353, l. 8.

[39] This moment of subjective arbitrariness in accessing the material is determined contradictorily in Kant's philosophy as well. On the one hand, he acknowledged it, on the other, he dismissed it: The "concept of matter at all" should be "empirical in itself", but could be gained without "special experiences" (Kant 1786, p. 472).

[40] Ruschig 1997, pp. 193 f.

[41] *Cf.* the example above of the connection between the continuous power of affinity and the specifically excluding property of salts.

[42] Bulthaup 1975, pp. 141 ff.

[43] *Cf.*, for example, Luhmann 1984, pp. 30 ff.

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