

DISTILLATION TECHNIQUES FROM THE CLASSICAL GREEK ANTIQUITY TO THE LATE HELLENISTIC ERA

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1. INTRODUCTION

Tracing the history of distillation as a chemical technology in ancient Greek and Hellenistic times poses several challenges.

From the point of view of *history of concepts* and ideas a serious obstacle is the evolution of terminology. Neither "chemistry" nor "distillation" are terms that already existed in the period considered here, nor is their translation into terms used at that time a pure linguistic task. Theoretical context and practical experience have to be described in terms of the cultural milieus considered in order that possible equivalences or approximations to our current terminology (at least as far as the key words are concerned) can be established. Special attention should be attributed to the philosophical background. Fortunately there is a lot of solid philological work already conducted on this field, a fact that facilitates the hermeneutic approach of the present study.

Another approach could focus the *apparatus* used. Distillation considered as a technology can be traced in different scientific and cultural milieus on the basis of apparatus characteristics. This approach, however, presupposes accessible sources of information and a high level of explanatory confidence, which depend again on philological and archaeological work. A special difficulty is associated with the importance of illustrations. For several more or less obvious reasons (special skill demand in copying illustrations of manuscripts, lack of appropriate material for long-life copies, less confidence attributed to illustrations than to text etc.) illustrations constitute a marginal and less studied part of classical and Hellenistic heritage[1]. Even if enough material is available, however interpretation and analysis usually imply a background of physicochemical explanation that owe their legitimation to the present state of scientific knowledge, since this knowledge state claims its explanatory validity on all preceding periods.

A complement of great importance for both issues mentioned is the *spectrum of products* processed or obtained through distillation (or equivalent procedures) at different periods. Actually the question of raw materials and their distillative transformation into products such as alcohol, medicines or perfumes could constitute a third approach of restructuring distillation history. Historical studies that have focussed such products (e.g. [2], [3]) could yield valuable material. The great advantage of this approach is the relative abundance of recipes mentioning or allowing the association with distillation processes in the ancient literature in comparison to descriptions of ancient Greek or Hellenistic distillation apparatus. A serious disadvantage of this approach is the historical variation in the correlation of processing technique (distillation) and processed products. Again the implicit current abstraction (i.e. theory) level tends to superimpose on past data, unless philological and historical scopes compensate the epistemological disequilibrium[4].

History of technology has to integrate all three approaches, since obviously none of them can yield independently a methodically coherent historical reconstruction of the subject considered. In the present study historical references from classical and Hellenistic times to what could be nowadays ascribed as distillative processes will be recapitulated and put into relation to dominant theoretical contexts. Deviating from the

common tradition of associating ancient and Hellenistic chemistry with platonism, neoplatonism and pythagorean concepts, this study intends to trace correlations between historical evidence of distillative concepts and practice on the one side and aristotelian ideas on the other. It will therefore focus the history of concepts in order to enable the construction of a hermeneutic basis for revisiting texts and illustrations concerning distillation apparatus.

2. TERMINOLOGY AND PRODUCTS OF REFERENCE

The modern technology historian who studies distillation concepts and practice in the antiquity carries the contemporary understanding of the term, i.e. the notion of a process which consists of turning a liquid to vapour by heating, cooling the vapour and collecting the drops of liquid that condense from the vapour. Further connotations include driving out or off impurities by means of the process described above as well as disclosing substances from their "concealment" in mixtures. It should be stressed that the word "distillate" in the sense of distilled liquid did not come into use before 1860[5, p. 69]. Even in the Middle Ages the word "water" was used for distilled liquid, a term that conducts back to aristotelian nomenclature. Our verb "to distill" has different meanings like "to trickle down; to flow gently; to melt into or dissolve in; to let fall; to give forth, impart, infuse, instil; to extract the essence of a plant; to transform, produce or extract by distillation; to extract the quintessence off, to drive volatile constituents off", whereas the original meaning of the Latin "destillare" as well as of the modern greek "απόσταξι" is "to drip down"[5, p. 70]. We should not forget also that "sublimatio" is a term strongly related in the Middle Ages to the phenomena considered here, in the sense that a greek term (e.g. ἀρσις in Zosimos' texts) can be found translated by "destillatio" as well as by "sublimatio", the latter being etymologically nearer to the original greek term, although it describes nowadays a different physical phenomenon.

Explicit descriptions of distillation and products obtained through such processes can be found already in classical texts. In the 2nd book of his "Meteorologica"[6] describes Aristotle how to obtain drink water from sea water: "Salt water when it turns into vapour becomes sweet and the vapour does not form salt water again, when it condenses. This I know by experiment. ... If one plunges a water-tight vessel of wax into the ocean, it will hold, after 24 hours, a certain quantity of water, that filtered into it through the waxen walls, and this water will be found to be potable, because the earthy and salty components have been sieved off" (358b, 17-35).

Another example is mentioned by Dioscorides (1st cent. AD) in connection with the preparation of tar or pitch water ("pisselaion")[5, pp. 15-16]. For this purpose pitch oil was boiled and large woollen sponges were suspended from the mouth of the boiling vessel to imbibe the evaporating substance. By subsequently squeezing the woollen sponges tar water was obtained. Further references to dry distillation in the manufacture of charcoal are made by Theophrast and Pliny.

It would be a very ambitious task to trace further products in distillation-like descriptions of ancient greek texts or to suspect distillation techniques behind products mentioned in such data. Some authors like R. J. Forbes are categorical: "Nor does chemical technology in [the Greek] Antiquity show any signs of the application of distillation. It is not used in the manufacture of alcoholic drinks, nor in the oil- and fat-industry or in the manufacture of perfumes and essential oils or cosmetics"[5, p. 15]. Others like H. Diels defend hypothesis, according to which several substances obtained through distillation or sublimation were known in certain circles in the early or late Hellenistic times but were kept secret by the Alexandrian chemists and priests[4, 7]. It is uncertain, however, whether certain apparatus or preparative methods later identified as distillation techniques were consciously associated with such products.

Certainly there is a large literature on Greek and Hellenistic chemistry[8], though neither the word "chemistry" nor "alchemy" was used, but mostly the reference to

The Work or The Divine and Sacred Art, even by Zosimos, from whom we have the first reference to the term "χημεία"[7]. The itinerary proposed here can not completely circumvent the well-known characteristics of the ancient Greek and Hellenistic chemistry[7, 9], namely pythagorean language, platonian and neoplatonic metaphysics, egyptian practice in manufacturing glass, precious stones and metals as well as syrian astrology. These characteristics, however, are mostly related to ceramics, metallurgy and other applications than distillation, and have been treated accordingly by other authors (e.g. [10]). Mystic elements and religious aspects, although of great interest for understanding connotations and modifications in the cultural background, would surpass the frame of this study. Of special importance for the purposes of this study are the aristotelian theory of the elements and their changes as well as the Hellenistic descriptions of distillation apparatus.

3. THEORETICAL BACKGROUND - THE ARISTOTELIAN HERITAGE

Although the contemporary scientific explanation of distillation bases on thermodynamic principles used in mass and heat transfer theory between different states of matter, most of the aspects mentioned above, notably the process character, purification, building of vapours in upward direction, building (condensing) of liquid and dripping down, can be traced back to greek texts of the classical or Hellenistic times. The main concept of change of the states of matter is expressed in the Greek antiquity in the Four-Element theory of Empedocles. The four elements, i.e. fire, water, air and earth, correspond, according to Plato's theory, to ideal geometric bodies. On this basis changes from one element into another are explained in "Timaios" through geometric transformations.

A key figure for understanding phenomena involving distillation is the cycle of water in nature. Plato writes in "Phaidon", cap. 60: "The origin of rivers is this: The water, rising by sun's heat, falls back in the form of rain and collects in a large cavern ...". Aristotle explains the same complex in his "Meteorologica" in a more elaborate way[6]. He departs from a "first matter" which can be rarified by more heat and condensed by cold, i.e. by the active qualities of matter. The description of change (coming-to-be or passing-away) as a *process* by means of the four primary qualities as contraries (hot vs. cold, moist and dry) is a crucial contribution of Aristotle to the theoretical background of distillation processes. In comparison to other philosophers Aristotle is the representative author for describing transition and for stressing the aspect of duration of changes. That is why we will insist on his works "Meteorologica" and "On Coming-to-be and Passing-away" while looking for the linguistic and philosophical roots of distillation.

There is a strong hypothesis of considering the 4th book of Aristotle's "Meteorologica" as his "chemical treatise"[11]. In looking for the theoretical background of distillation, however, we have to consider this book together with the 2nd book of "De generatione et corruptione"[12], the Book of the Elements, since both books may belong to an older unity, a work concerning the elements, the four qualities and change processes effected by the active qualities, the hot and the cold. An important issue in the Book of the Elements is associated with the touch/contact (ἀφή) as the principle of the bodies accessible through the senses (329b, 7). From this point Aristotle deduces a primordial role for the active qualities (contraries) hot and cold. The rest of qualities mentioned in 329b-330b are deduced from the effects of the active qualities with the passive ones (moist and dry). Thus a theory of physicochemical effects is developed on the basis of the sense of touch/contact, whose systematic backbone is demonstrated in the 1st book of "De generatione et corruptione" (322b-323b). The hot and the cold are masters of the matter since they act as generative powers, controlling and transforming the dry and the moist[6, 379a].

Here we have a coherent model of transformation of the states of matter under the influence of heat transfer, a model containing all the components used later to describe

and explain distillation in terms of modern science. In fact Aristotle uses water evaporation and condensing as example[6: 358b, 17ff]. Moreover he underlines the rate of change between different states, since every element can come-to-be from every other element, though the velocity and the grade of difficulty depends on the qualities involved in the transition[11:331a, 20; 6:357b, 34ff]. This pragmatic *intrinsic time pattern* for state transitions was conceived later rather as a metaphysical postulate and had an important influence on the development of theory and practice of distillation processes up to the Middle Ages[13].

The crucial importance of hot and cold in producing the effects responsible for what could be understood as distillation processes involving different states of matter in contact to each other is demonstrated in the Book of the Elements, 329b, 25-30. Hot is the quality which brings together bodies of the same species (ὁμόφυλα) and separates those of different species (ἀλλότρια), whereas cold is the quality which brings together all bodies. Apart from explanations like giving off salty sweat by a human body as a result of increased heat the processes effected by the hot and the cold are amply described in the 4th book of "Meteorologica". After including all active operations of the hot on physical bodies under the name of *digestion* (πέψις) and those of the cold under the name of *indigestion* (ἀνεψία) (379b, 10-12), Aristotle enumerates further subclassifications under these main transformation classes. Examples like the fermentation of wine, the ripening of the nutriment in fruit, the inflamed swelling on a human body, the cooking of food or the drying of earthenware demonstrate the wide sense in which the term *digestion* should be understood. In fact the effects of the hot and the cold are understood as digestion processes, as transitions between the raw and the cooked (boiled). In this sense the chemistry of Aristotle conceives and describes transformation of matter like the human metabolism[14].

In the later tradition through the Hellenistic times up to the Middle Ages the rational character of the aristotelian chemical theory lost a considerable part of its impact, whereas metaphors and terms apt to mystic associations gained popularity under the influence of neoplatonism, religious streams and oriental mysticism. A typical example is the *digestion* concept which, deprived from a part of the aristotelian context explained above, found its way through the Hellenistic era to the Middle Ages and gave birth to new syncretical concepts. One of these concepts postulates that the spirit should be first developed through moderate heating in digestorium in order to be subsequently separated through distillation. Many transitions described by Aristotle gave their names to apparatus used by the Alexandrian chemists, however the operations conducted in them remain partially obscure[5, p.27].

4. DISTILLATION APPARATUS - THE HELLENISTIC HERITAGE

The clash of classical Greek science with Egyptian practice in metallurgy, glass manufacturing and ceramics in Hellenistic Alexandria, as well as the influence of gnosticism, neoplatonism and oriental spiritual trends gave birth to a syncretical formation which has often been called "Alexandrian Alchemy". It was characterized more through mystical and speculative elements than through aristotelian rationalism and produced a vast text corpus, fragments of which reached our days in the form of later manuscripts dating from the 10th to the 18th cent. in several collections[8].

As far as literature concerning distillation is concerned, the available information is due to the school of Maria the Jewess, Comarius, Hermes, Cleopatra and possibly Agathodaemon (1st - 2nd c. AD), as well as to authors of the 3rd and 4th century including Zosimos, Africanus, Heliodorus, Pelagius and others. The manuscript texts contain several descriptions of processes and instruments used for distillation and sublimation. The most informative descriptions are given by Zosimos of Panopolis, especially in his works "On Instruments and Ovens" and "On the Trivikos and the Tube"[8: 2,224-238]. Numerous references in the manuscripts concerning illustrations prove the hypothesis that the original texts were accompanied by illustrations too[1].

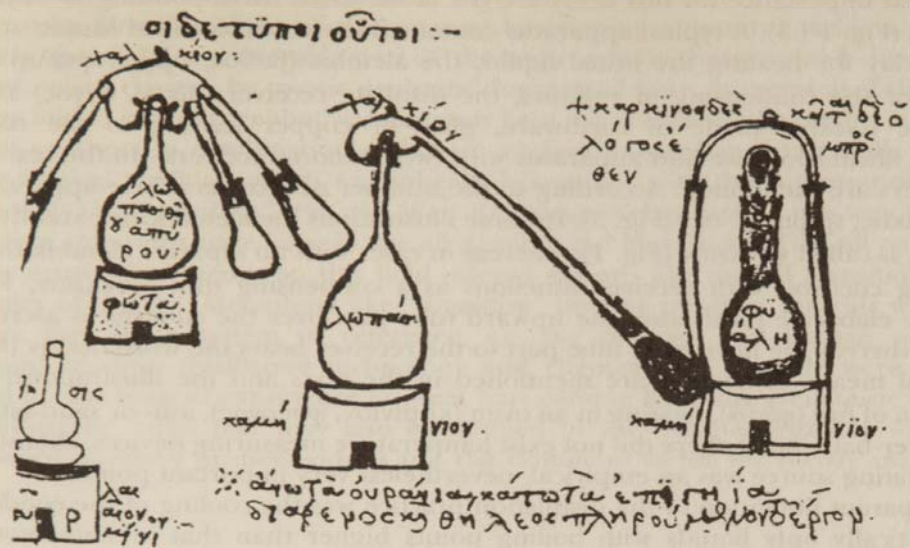


FIG. 1 Hellenistic distillation apparatus with alembic (8: 1, 161)

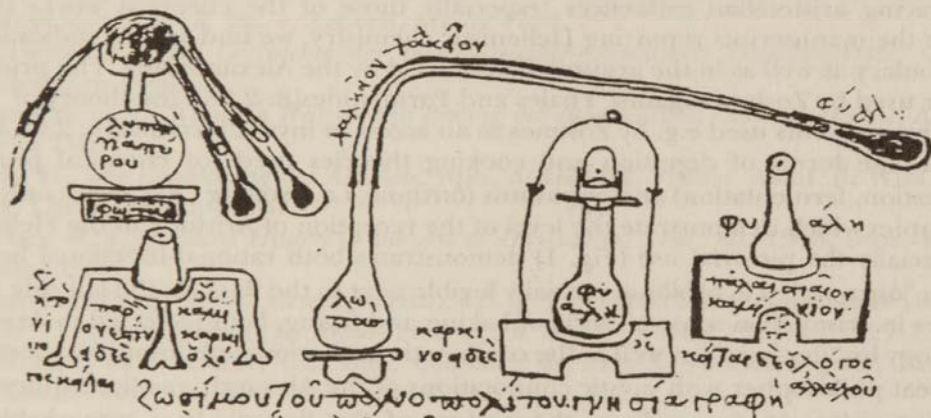


FIG. 2 Hellenistic distillation apparatus with condensing tube (8: 1, 163)

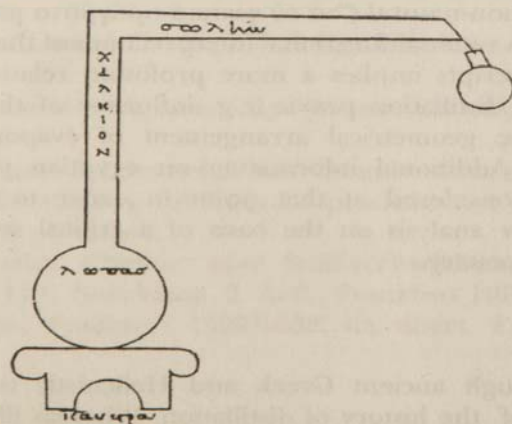


FIG. 3 Hellenistic distillation apparatus with condensing tube (8: 1, 140)

Of great importance for this study are the illustrations corresponding to distillation apparatus (Fig. 1 - 3). A typical apparatus contained the cucurbit called *λωπιάς* or *λέβης* made of clay for heating the initial liquid, the alembic (*βάθος*, *άμβιξ*, *φιάλη*) as the element for the condensing of vapours, the distillate receiver (*βίκος*, *άγγος*) and the outlet-tube (*σωλήν*) made of earthenware, glass or copper leading to the receiver. In several illustrations we find apparatus with two or more receivers - in the texts up to six receivers are mentioned. According to the number of receivers these apparatus are called *δίβικος*, *τρίβικος* etc. (Fig. 3). In some illustrations the alembik, apparently made of copper, is called *χαλκεῖον* (Fig. 1), whereas in cases with no separate alembik the tube connecting cucurbit with receiver functions as a condensing unit (*χαλκεῖον*, Fig. 2). In a more elaborate illustration the upward tube part over the cucurbit is ascribed as *χαλκίον*, whereas the horizontal tube part to the receiver bears the word *σωλήν* (Fig. 3).

Several means of heating are mentioned in the texts and the illustrations: direct application of fire (*φῶτα*), heating in an oven (*καμίνιον*, *φούρνος*), ash- or sand-bath and finally water-bath. Since there did not exist temperature measuring devices, choosing the proper heating source was an empirical, nevertheless very important point.

An apparent limitation of the distillation practice was the cooling of the condensing unit. Practically only liquids with boiling points higher than that of water could be recovered efficiently[5, p.21], an argument that is often used to reject the hypothesis that Alexandrian chemists could have isolated alcohol. Improvements of the cooling system using water to moisten the alembic are reported by Zosimos[8: 2,224].

In tracing aristotelian influences (especially those of the chemical works treated above) in the manuscripts reporting Hellenistic chemistry, we find several indications in the vocabulary as well as in the argumentation used by the Alexandrians. The principles of matter used by Zosimos against Thales and Parmenides[8: 2,88], the theory of active and passive elements used e.g. by Zosimos as an access to mystic formulae[8: 2,92 & 152] as well as the terms of digestion and cooking theories used for chemical processes (e.g. digestion, fermentation) and apparatus (*ῥοπήσις*, i.e. broiling ; Fig.1) are only some few examples which demonstrate the level of the reception of Aristotle in the Hellenistic era. Especially the pictorial use (Fig. 1) demonstrates both rational-functional heritage (the term "*ῥοπήσις*", i.e. broiling, partially legible next to the flask on the left side down, comprises in aristotelian sense all sorts of baking and frying, being affected in Aristotle's terminology by "dry heat") as well as the combination of rational philosophical postulates of the great philosopher with mystic connotations of the Alexandrians (inscription "*ἄνω τά οὐράνια, κάτω τά ἐπιγῆα*" on the bottom of the figure). It is remarkable that Aristotle's works were often read allegorically (e.g. by Olympiodorus) on the assumption that the Greek philosopher wrote on purpose enigmatically modifying meanings of words (one could recall the *digestion* terminology) in order to disorientate the reader from natural things to non-natural ("*τά οὐ φυσικά πράγματα μεθοδεύωσιν*") [8: 2, 70].

On the other hand a rational-functional interpretation of the apparatus described or depicted in the manuscripts implies a more profound relation between aristotelian theory and Hellenistic distillation praxis (e.g. influence of the hot and the cold on separating components; geometrical arrangement of evaporating and condensing apparatus, Figs. 1-3). Additional information on egyptian pottery, perfumery and medicine should be considered at that point in order to avoid misleading over interpretations. Further analysis on the basis of a critical study of the illustrations available is certainly necessary.

5. CONCLUSION

The itinerary through ancient Greek and Hellenistic times revealed a rather heterogeneous figure of the history of distillation. Whereas illustrations of distillation apparatus and some text references reflect the influence of aristotelian rationalism (e.g. upward/downward flow, transition concept, effect of active qualities/contrarities hot

vs. cold), the Hellenistic language is more influenced by platonism, gnostic elements and pythagorean formulae. Even if reference to functioning apparatus yields a picture of flourishing technology, the main part of the text corpus is characterized - in contrast to the aristotelian clarity - by mystic goals and hermetical tone. It seems as if the rational heritage folded into a space that was minutely kept inaccessible to the public. Here Greek rational concepts in combination with east mediterranean handicraft skills produced a technological tradition which was inherited (together with the superimposed mystic terminology) by Byzantine, Arab and West European Alchemists. In this way Hellenistic distillation apparatus have been in use all through the Middle Ages[15] till our time.

The aristotelian theory on this field offered notions like that of transition and the principles of change. Metaphors like "digestion" became popular, but this was not the case for the whole system of reference, i.e. the cooking and human metabolism analogon! Modern distillation technology and chemistry as a whole were gradually formed on the basis of experience (a great part coming from the Hellenistic tradition!) and "objective" rules that may also be applied to the human organism - but one's experience on one's proper body is not the dominant factor for theory making any more.

NOTES

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ΠΕΡΙΛΗΨΗ

ΤΕΧΝΙΚΕΣ ΑΠΟΣΤΑΞΗΣ ΑΠΟ ΤΗΝ ΚΛΑΣΣΙΚΗ ΕΛΛΗΝΙΚΗ ΑΡΧΑΙΟΤΗΤΑ ΜΕΧΡΙ ΤΗΝ ΥΣΤΕΡΗ ΕΛΛΗΝΙΣΤΙΚΗ ΕΠΟΧΗ

Κ. ΚΑΝΝΑΒΑΣ

Η εξέταση επιστημονικών ιδεών και τεχνικών δεξιοτήτων του παρελθόντος μπορεί να οδηγήσει στον πειρασμό εξηγήσεων και κατηγοριοποιήσεων βάσει της σύγχρονης κατανόησης των φυσικών επιστημών. Για την περίπτωση της απόσταξης, στα πλαίσια των ιδεών και τεχνικών της αρχαίας ελληνικής ιστορίας, μπορεί να αναχθεί στην κλασική εποχή, ενώ είναι διαθέσιμες πιο λεπτομερειακές πληροφορίες που αφορούν στην υστερή Ελληνιστική περίοδο (1ος μέχρι 3ος αιώνας π. Χ.).

Ακόμη κι αν -εφόσον στηριχτούμε στη σύγχρονη επιστημονική θεώρηση- η αρχαία πρακτική απόσταξης φαίνεται ισότιμη κατά βάση με σύγχρονες πειραματικές μεθόδους, εν τούτοις το θεωρητικό υπόβαθρο και οι αναφορές στα συμφραζόμενα κάθε περιόδου υποδεικνύουν μια διαφοροποιημένη ερμηνευτική προσέγγιση.

Η Αριστοτελική μεταφυσική, οι νεοπλατωνικές αρχές, όπως και η σύγχρονη ιατρική πρακτική και οι συσκευές της κουζίνας παρέχουν τη δυνατότητα μάλλον της βαθύτερης κατανόησης των επιστημονικών επιτευγμάτων στο πεδίο της Ελληνικής και Ελληνιστικής απόσταξης, παρά της προσφυγής στις καθολικές έννοιες της σύγχρονης θεωρίας μεταφοράς της θερμότητας και της μάζας.