Techniques and Innovations

William Peckitt, George Berg

Vitreous-Color Experiments in Mid-Century Britain

William Peckitt worked as a glass painter-stainer in York. Self-taught, he experimented throughout his career, receiving a patent of invention in 1780, and assembling a manual of practices that described his techniques and explained their chemistry. George Berg, London-based and also self-taught, carried out a program of experiments with glass- and enamel-making, doing so around the busy schedule of a professional musician. He left a series of experiment books that outline his project, its successes and its failures.

There is no information that explains why either man was drawn to vitreous-colormaking experiments. Neither Peckitt nor Berg had family or other demonstrable connections to the occupation and no clear statement can be found in their writing. Each demonstrated an interest in the art and the scientific principles of glassmaking, and each served that interest through reading, discussion, and practice. Both left concrete examples of their engagement. From those remainders we can learn much about the nature of experimental practices in eighteenth-century glassmaking industries. We can compare the approaches of two archetypes of the Enlightenment: the intellectually engaged manufacturer and the dedicated, methodical amateur.

Early Interest and Training

William Peckitt

William Peckitt was well known throughout England in his lifetime. Although the products of his workshop included the prosaic vases, bowls, and other glassware that would appeal to a broad base of consumers, Peckitt is remembered now for painted- and stained-glass—colored plates and pictures, especially somewhat idiosyncratic portraits. His work included commissions for Horace Walpole, for the cathedral at Exeter, and for the fellows of New College, Oxford, as well as for patrons around York.

Throughout his life, Peckitt never referred directly to popular perceptions of glass-painting or -staining as a lost art, but he did note it as an unusual practice. He described his skill as one learned through years of experiment, andconsensus among his biographers is that this is true; the traditions of glass painting that had flourished in medieval York were long dead by the eighteenth century.[1] Apparently, Peckitt's interest began when he was young; at age 2, he had sufficient confidence in his abilities to advertise in a local newspaper.[2] The city leaders encouraged his work, awarding him the Freedom of the City two years later.[3]

George Berg

George Berg's notebooks, our primary source of information about his work as a glassmaker, locate the beginnings of his interest to approximately the same period as Peckitt's. Beginning in November 1759 and continuing until September 1774, Berg undertook more than 670 experiments with colored glasses. He recorded his trials in small paper notebooks, interspersing them with his own and others' comments about their quality, including explanations based on his readings in chemistry.[4] Berg's notebooks also include miscellaneous notes about purchases, readings, conversations, and occasionally hints of his life away from the furnaces. From these records we know that in this fifteen-year period, with one long break (July 1771 to September 1772), Berg carried out between one and five glassmaking trials almost every week.

Was Berg led to vitreous-color production through an interest in chemistry? Was he determined to invent something useful? Was small-scale enamel production suggested as a way to supplement his earnings as a musician? Berg's comments suggest that a manufacturing prize may have been a goal, although the Society of Arts offered no regular prize for the colors he busied himself with, and there is no record of any submission or correspondence about his inventions. Despite friendships with several prominent Society members, and his own election to membership in 1769, Berg was not closely involved in Society business.

But if we don't know why Berg learned his skills, we do have a good sense of how. Berg read, thought, planned, tested and discussed. The notebooks contain many transcriptions from chemistry books and notes from lectures and private conversations—conversations with William Lewis; with Samuel More; with Stephen Hall, owner of the Falcon Glasshouse; with Colebron Hancock, a prominent London glass merchant, and with other merchants, apothecaries, goldsmiths and enamellers. He owned many books about chemistry and glassmaking, including Peter Shaw's *Chemical Lectures* , William Lewis's *Commercium Philosophico-Technicum* , James Millar's *New Course of Chymistry*, and Godfrey Smith's *Laboratory, or School of Arts.*

Both Peckitt and Berg were self-taught glassmakers, experimenters who achieved some measure of success within the parameters of their specific interests. How did each combine chemistry into his work? Appraisals of the work of both men by modern writers have tended to express regret that their studies antedated the chemical reforms of Lavoisier and others, quickly move to other subjects.[5] Consideration of each manuscript and, in Peckitt's case, some other writing indicates that their investigations gave prominence to current theories about chemical combination and to efforts to reconcile the practical with the operational or philosophical. What did they believe they were doing?

George Berg's Experiment Books

It appears that George Berg knew little about chemistry, chemical practices, or glassmaking when he began to experiment in 1759. It is clear that he recognized a need to quantify his work in scientific terms, as he incorporated assessments of his products into his notes, and used those assessments to develop further experiments. Results of many glassmaking trials were weighed in air and water, and their proportional gravity noted. The significance of this number to Berg is not clear; perhaps he recorded it to compare formulas or results. The calculation may be related to Edward Hussey Delaval's work on this subject, read at the Royal Society of London in January 1765 and published as a pamphlet later that year.[6] In that paper, Delaval related color to density, as specific gravity, suggesting that greater density should reflect the more refrangible rays.

George Berg's Notebooks

Bk#	Expts#	Earliest date	Latest date
1	1-95	10 Nov 1759	10 Nov [1762]
2	96-132	11 Nov [1762]	28 Jun 1766
3	122-222	5 Jul 1766	29 Jan 1768
4	223-377	6 Feb 1768	25 Aug 1770
5	378-514	1 Sept 1770	30 Oct 1773
6	515-672	6 Nov 1773	8 Sept 1774

Papers interleaved into Berg's notebooks, some on the backs of old bills and others on what seem to be lyrics or letters, record compositions to try, expenses, comments, suggestions, and advice that may have come Berg's way during a lecture or conversation. Not all relate directly to glass- or enamel-making, but many refer to chemistry or the chemical operations that would be significant to his endeavor. Berg recorded a method for keeping vinegar from developing dregs and for building a primitive (and probably not very effective) fire extinguisher, and he inventoried natural and artificial acids by their increasing strength. Other lists include weights of materials and chemical symbols for common substances.

> All bodies may be chemically considered under three Tribes; Alkalies, Acid, or Neutrals. Alkalis have this essential property, that when mixed or united with Acids, they constitute Neutrals. But a more common mark of an Alkali is that it turns Syrup of Violets green, as an Acid turns it Red, whilst the admixture of a neutral Body does not alter the colour of that Syrup.
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> George Berg, *Experiments in Chemistry 1759–1774*, Notebook 1, (n.d.), Dudley Archives Centre RBC/7/8/1 (No longer available). Quoted by kind permission of Mr. D. Williams-Thomas.

The first pages of Berg's first notebook (there were six, now bound into a single volume) record citations of chemistry from chemistry books and an inventory of materials and costs. The list includes chemical equipment (two glass viols [*sic*] with stoppels, crucibles) and such materials as salt of tartar, double-distilled vinegar, charcoal, and gold. The page has several dates, up to April 1767, and the repeated purchase of materials such as borax suggests that it was a running tally of certain expenses. The early notebooks are written from two directions; the reversed portions contain observations and comments rather than experiments. Berg seems to be trying to divide this working universe into the acids, alkalis, and neutrals he mentions in the beginning of the recto of the first notebook. By the third, he has abandoned the effort to maintain those distinctions.

From the start of the records until August 1760, when work was interrupted by a journey to Italy, Berg completed fifty experiments. During these ten months, he consulted regularly with Samuel More and Edward Carter, a jeweler, enameller, and goldsmith.[7] Berg's working routine, inasmuch as it can be deciphered, was to use the technical facilities he needed during their slow periods. He would go to the glasshouse on Saturday mornings to prepare ingredients; usually samples were ready to be fired about midday. Once they were placed in the furnace, Berg would leave, returning late Sunday or early Monday to collect the results and discuss them with the glass masters, workers, or others. Tests that used the smaller, more easily heated enameller's or goldsmith's furnace could take place at midweek. For nearly every trial Berg notes the furnace used and it is clear that he relied on several glasshouses for all his experiments. The physical location does not seem to depend on the subjects of his experiments, and it may have been based on other activities taking place at the different manufactures.

Gemstones and Enamels

Berg's notebooks demonstrate his reliance on recipes that could be tested in small batches and revised or adjusted quickly. This facilitated exploration of underlying chemical principles as their importance became apparent. His trials allowed Berg to explore production techniques and materials, but his notes about that work suggest that his interest was intellectual adventure as well as a contribution to public understanding. Berg's early experiments had two focus points: artificial gemstones and glasses that would be used for enamelling or painting ceramic glazes. The interest in glass gemstones, in particular, suggests an underlying commercial purpose to Berg's project. A strong demand existed for these materials, which were used by manufacturers of decorative objects. Techniques for making artificial gemstones were a common subject in practical manuals about glassmaking, and they were studied by chemists and physicists as well. Eighteenth-century studies were connected to general interests in the natural world, to more-particular interests in crystallization, and to the availability of Roman-era carved gemstones and glass. In England, the combined practical and scientific interest probably peaked after Berg's death, with the Duke of Portland's purchase of the Barberini vase, its public exhibition, and Josiah Wedgwood's copies of it.[8]

In observations recorded at the beginning of his first notebook, Berg further corroborates his interest in creating artificial gems. There is a passage about lead, as ceruse or as minium, as the basis to imitate all colored gems. There is a description of ways to reuse rejected "stones" in the glasshouse—those with a spar base can be used to make lime, a substance needed for other glassmaking techniques. Gems made from a crystal base can be broken up and reused for glassmaking.

Berg continued to work with glass gems, even as his interest shifted to other forms of vitreous colored objects. An inserted paper, dated 16 September 1763, lists proportions of materials appropriate for the making of the plaster molds that would shape gems and, in 1771, he noted that he gave Count Moussine-Pouchkine, the Russian ambassador to London, a faceted glass gem made according to a recipe recorded about two years earlier.[9]

Berg also experimented with ruby glass made from purple of Cassius. There are notes from a discussion with More about dyeing silk purple, perhaps related to discussions of the creation of crimsons and purples for textiles taking place about that time at the Society of Arts.[10] Later, Berg began to experiment with opaque white glass, suitable for use with enamels, that was a regular feature of the Society's premium lists. Those trials continued for several years and, by Experiment 147, dated 9 August 1766, Berg had achieved appreciable skill. He noted in the margin that Hancock considered the result of that experiment as his best enamel. In November 1769, Berg recorded that he made a small bottle from the result of Experiment 304, and notes that he showed this recipe to several people.

By the early 1770s, however, Berg's interest developed in a slightly different direction. While the experiments he recorded continue to build from previous trials, his comments indicate increasing concern about the mechanism or rationale of the imperfections he notes. This suggests that, while testing new glass formulas for different uses, he was also creating a personal program to study affinities of acids of sea salt, niter, and vitriol. That project was never completed, but Berg's reach as a chemist and a glassmaker expands noticeably as a result. Experiment 98 suggests a mechanism for the formation of color based in part on affinity and calcination. Other trials suggest a concern for analysis rather than product. Berg conducted experiments to determine the composition of a frit taken from a glasshouse and, from this, to determine the proportions of materials needed to make a good glass. His analysis involved repeated weighing and extraction of a sample, removing first salt and then arsenic and, finally, lead. Apparently the analysis was not a success: His results differed from what More told him the proportions of glasshouse frit should be. He had access to that information, not only from More but also from other glassmen and from his library, and so this experiment may have been an operational exercise rather than an attempt to decipher a professional secret.

Experiment 98.

¾ oz: sand 1 oz: minium ¼ oz: Borax ¼ oz: Putty with half of half a Dram of the precipitate of Copper, one Hour in fusion produces an opake composition, the bottom part of a pea green; about the breadth of a goose quil on the top, was of a variegated redish brown thus I suppose the Copper & Minium would not mix, the Copper flew upwards & made the brown part, the bottom part acquired no green but that the minium gave. . . . I believe the blackness on the Top of the Composition Ex: 96 is occasioned as follows the Borax extricates the Marine Acid from the Nitre which is thrown to the surface & there remains being uncapable of vitrifying. I suppose the cause of that redish colour is occasioned as follows: the Minium assists in some manner to calcine the copper yet further than in was before & uniting together produces that effect so I think no minium shall be used with Copper in any form whatever.

George Berg, *Experiments in Chemistry 1759–1774* Notebook 2, Nov 23 [1762], Dudley Archives Centre RBC/7/8/1 (No longer available). Quoted by kind permission of Mr. D. Williams-Thomas.

About this same time, Berg recorded More's technique for determining the amount of phlogiston in a body. This further indicates that Berg was exploring the chemistry of good glass—not only the role of affinity, but also the function of phlogiston in glass and colormaking, and the connection between color and proportional density of metals. In his notes he considers the composition of Prussian blue, and there he includes a recipe taken from Peter Shaw's *Chemical Lectures* and adds to the recipe comments about the role of oxblood as the source of phlogiston. He also notes that any other phlogiston-rich material—for example, soot—was a potential substitute, a common belief at the time.

Expt. 593. Best purple on silver.

1 ½ oz Sand, 1 ½ oz rough Nitre, 2 ¼ oz minium & 2 drams english Manganese uncalcin'd. 1 hour in Carters Furnace. This Carter try'd on fine Silver, it is too hard, the silver having melted before the enamel. From this I am led to believe that Manganese prevents the fluxing of the Glass when in a large proportion. Pickavey tried this on Old Sterling Silver, it run very well, is a good purple, but wants to be a little brighter.

George Berg, *Experiments in Chemistry 1759–1774* Notebook 6, [10 March 1774], Dudley Archives Centre RBC/7/8/1 (No longer available). Quoted by kind permission of Mr. D. Williams-Thomas.

Berg's confidence in his chemical understanding reached new levels by the beginning of the fifth notebook, or late in 1771. Although he doesn't use chemical notations in his formulas until the sixth notebook, a list of these symbols with their proportional gravities, copied from *Chambers Dictionary*, appears at the front of Notebook 5.[11] Also at this point, Berg began to attribute comments to Richard Dovey, a goldsmith who worked in the London district of St. Clement Danes.[12] Dovey's name does not appear earlier, suggesting that their acquaintance dates from this time, and it may be related to Berg's interest in color for enamels; gold was a common (if luxurious) substrate.

Berg's shift in focus to enamel colors from fake gems required a corresponding shift in formulas and in expectations. Enamels required a different degree of transparency, and coloring materials used for this purpose needed to adhere to a support, either a metal or a white enamel base. Berg's comments in this portion of his notebook refer to the results of trials on substrates of silver and gold, and he complains of greasy-looking colors and colors that lack the depth of color required of good enamels. Based on his comments, Berg's results began to improve late in 1773, and 23 of the 110 trials made during his last year of work—including a blue for silver, and a red for gold—are marked "best." Several others were "very good."

The End of Berg's Experiments

Why did George Berg's experiments end? Had he achieved his goal to create viable new formulas for colored glasses? Had he achieved his goal to learn chemistry? Was it that Berg's other duties occupied him so that he lacked time? Campbell suggests that the glass tax, instituted in 1745, caught up with Berg so that it became too expensive to continue legally or too dangerous to flaunt the tax.[13] But then, as Campbell himself wonders, why wasn't this a problem in the fifteen years preceding? Was Berg, in 1774, too busy to complete the trials that might have led to an award from the Society of Arts or to the sale of his formulas to another glassmaker? Was a seventh notebook, one he may have been filling at his death, lost?

We might never know the answers to these questions, but there are nonetheless many interesting facets to George Berg's venture into glassmaking. As an amateur chemist and an amateur glassmaker who had a close relationship with a range of experts—chemists and other scientists, glassmakers, enamellers, goldsmiths, and connoisseurs—Berg's endeavor suggests another side to the combination of practical and intellectual exchanges that were possible in the eighteenth century. More typical relationships are demonstrated not only by the formal or informally constituted groups but also by the practice-driven investigations of François Gonin, Arnaud Vincent de Montpetit, Jean-Baptiste Pont and Pierre-Joseph Macquer, and others. Berg's manuscript notebooks offer an opportunity to consider the changing interests of an amateur, to consider the depth of that interest and how his proficiency grew. They permit, in ways not offered by many other sources, a glimpse at the use of chemistry in practice: to plot projects, to explain behavior, to understand chemistry itself.

William Peckitt's Treatise

George Berg as seen from his manuscript notebooks is a curious and engaged experimenter. We observe the same traits in William Peckitt through his manuscript treatise, *The Principals of Introduction into That Rare but Fine and Elegant Art of Painting and Staining of Glass*, even though this is a different kind of work.[14] Peckitt first tried to publish his techniques in 1760; the manuscript is dated 1793.[15] We do not know, however, if this is the same document, a revision, or a later work. In this manuscript we do not have access to the thought processes and changes of mind found in a laboratory notebook. Instead, the treatise presents a culmination of Peckitt's understanding.

> All the Colours must be so addapted as to be fluxed and stained in the same degree of heat: and which is the grand Point of Composition. (Only known by these Receipts, and Practice.) And to know that degree precisely, is only by Custom, and the Trials taken out from the Furnace, when near sufficiently hot; from the bottom, middle height, and top of the lower iron pan.
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> Peckitt, William *The Principals [sic] of. . . Painting and Staining of Glass* (1793), York Museums Trust (York Art Gallery), York, England, MS. f.13r.

Peckitt's *Principals . . . of Painting and Staining Glass* reflects not a symbiosis of glassmaking and chemistry but an attempt to organize workshop coloring practices. In his writing, Peckitt engaged both chemistry and chemical philosophies, however. His attention to systematization was related to his experience and his position as a glassmaker. Peckitt followed typical formats, describing tools and quantities of materials to be used and linking his information to chemical understanding at critical points. Peckitt's manuscript includes seven types of recipes: fluxes, enamels, colorless glasses, opaque glasses, furnaces, techniques, and stains.[16] While experience will lead the user to the most satisfactory methods, Peckitt suggests, he offers the basic information—preparation of the different coloring materials and their application, details for setting up the furnace and for firing the different types of glass. A notable feature of his collection of recipes was the reformulation of colors to use a single firing, reducing time and cost as well as potential damage to prior-laid colors. Peckitt's manual does not explain how to make objects from its results, however, although this was a skill Peckitt possessed.

As both a glass-painter and a glass-stainer, Peckitt used color in different ways to create designs. The glass base or substrate could be clear or colored; other, different-colored glasses could be fired onto it. Those additional colors could be stains or enamels. Success depended on the correct combination of substrate and additions, but the combination of either or both gave differing degrees of transparency and thickness. In a testament to his other experiments, Peckitt in 1780 received a patent for creating multicolored cut-glass objects involving techniques included in his treatise.[17]

The order of Peckitt's manual brings the reader through the stages of glassmaking and glass-coloring as one might move through the procedures. It begins with formulas for fluxes, both general formulas and those designated for a specific kind of color, such as black or rose. Recipes for colored glasses follow. He mentions black, scarlet, white, brown, yellow, green, deep blue, purple, stone color, and blue, all colors found in objects attributed to him. Peckitt then shifts to describe the preparation of gold and silver as used to make rose and azure colors. In his recipe for purple of Cassius , he divides the preparation of materials from that of the precipitate, much as he separated the processes of colormaking into stages. In the latter part of the manuscript, Peckitt included compositions to color flint glass, crown glass and flint glass that could cover crown glass. The colors for these combinations included reds, yellow, blue, green, and purple. He also included a gold color, emerald, sapphire, amethyst, an opaque glass suitable for vessels, and colors for staining glass green and red. Peckitt's palette, like that for most vitreous colors, was fairly small, at most ten colors for any one type of glass.

Peckitt's Universal Order

Peckitt's treatise on glass hints at his ideas about color and color order as philosophical subjects. These ideas are partly confirmed by turning to a very different source, another book he wrote. *The Wonderful Love of God to Men, or, Heaven Opened in Earth* is a religious tract that describes the origin and workings of the world.[18] It is a determined if ragged book—the table of contents and the headings of each section, for example, almost never agree, and the language is dense with expressions that evoke both religion and science without clarifying either especially well. This genre of writing is not normally connected to late-eighteenth-century England, although there is no reason to believe that it died out completely between the more familiar periods of the late seventeenth and mid-nineteenth centuries. Peckitt's effort is not dissimilar from earlier or later attempts to create a cosmography that integrated science and religion. In certain respects it resembles Gautier's *Chroa-Génésie*, not only in the effort required to follow the argument of each author but also in that both men were principally artisans rather than theologians, physicists, or mathematicians.[19] Quotidian experience informed their cosmogony.

> These orders of holy espirits so diffused also through the vastness of the terrestrial Universe, are called the Elements: each one, in these orders respectively, is of the most perfect form, solid, yet elastic, substance: in area, wonderfully minute! but vary in proportion; and respectively named accordingly, from the greater, in area and power, to the lesser; (yet equal in each order) Earths, Acies, Waters, Electaes, Airs, and Fires the less and also the least.
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> William Peckitt, *The Wonderful Love of God to Men* (York, 1794), 14.

In *The Wonderful Love of God to Men*, Peckitt used his understanding of sciences, primarily a combination of chemistry and natural history, to explain the universe, with Bible quotations provided for corroboration. His world system was based on six different kinds of elements, each with specific forms and properties. They interact through attraction, rotation, contraction (a kind of internalized attraction), refraction, rebounding, and remission. For Electaes (electricity, more or less), Airs, and Fires—airborne particles, all—there are discrete sites where these actions may take place.[20] This makes each particle capable of combination in ways that seem to extend from contemporary affinity theories. Airs rotate within the ethereal Fires, and the inherently stronger forces of the Electaes act upon them both, creating a triplex medium, as Peckitt calls it.[21] These forces act on the remaining elements, Waters, Acies (acids), and Earths. Peckitt describes these three as spiritual bodies, largely acted on although capable of mutual attraction. The six elements are opposite and complementary, and together they fill the Void. No characteristic physical shape is assigned to these elements; although the explanation donates some of the functions of acids and alkalis to them. Peckitt explains the macrocosm as well as microcosm, using the activity of these same elements in the formation of the solar system, planets, the moon, gravity, the seas, volcanoes, comets, and the rest of the natural world. Each of Peckitt's elements when combined with others, is directed into a new shape by the divine power. Every element is thus adapted to serve the purpose for which it was designed; when that has been achieved, it becomes extinct and dissolves. There are four activities for these elements: cohesion or conjunction, which comes of an innate mutual attraction; division, which seems to be instigated by the presence of the elemental fire; gravitation, again caused by fires in their fluid state; and volatility, a counter to gravitation.

Discussion here of *The Wonderful Love of God to Men* would be, but for two details, as irrelevant as an analysis of George Berg's glees and sonatas. First is Peckitt's explanation of light, and the position of colors within that system and elsewhere. Second is the correspondence between the operational descriptions of Peckitt's universal system and his workshop practice. Because quotidian experience informs Peckitt's explanations, we can create a sense of how he understood the chemistry of glassmaking processes. His operational descriptions in the book and in the manuscript treatise complement each other.

Peckitt explains that elemental fires are the cause of both light and color. When the two kinds of fires, perfectly mixed and parallel, are "flying" in the same direction, there is no color. If, however, they exit obliquely from something transparent and colorless, such as ice, crystal, or glass, colors form. A drop of water can, by nature of the differing degrees of refraction for each of the rays, create a rainbow. If the fire particles are separated, as by a prism, or if they enter the pores of certain phlogistic principles or particles of bodies, then color appears. Vision is possible because of the refraction or inflection of these separated fire particles that occurs when they encounter an object. The nature of the element and its degree of attraction or repulsion to the fire particle determine whether the color seen is yellow, azure, or red (the sources of all colors) as the element intersects with and enters the pores of an object. Green is formed by the intersection of azure and yellow rays as they converge on the pores; it may be assumed that other secondary and perhaps even tertiary colors appear in the same way. Shades and tones—lighter and darker colors—result from the quantity of Fires present and their degree of recombination after separation.

Understanding Peckitt's Understanding

> Fires, in their flying state, when they meet in contact direct with Fires in their fluid state gravitating, by their force, elasticity, and attraction, they proportionally yield to each other in their form; but those by superior momentum, forcing these before them in right-lined rays; and these, others in like manner. And when form firm resistance they (elastically) refly, they pass great Space: but that force is the sooner Spent, the oftener they rebound: and when entirely So, they resume their fluid state, gravitate, or combine to bodies.
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> William Peckitt, *The Wonderful Love of God to Men* (York, 1794), 52.

Peckitt's language and presentation in *The Wonderful Love of God to Men* suggest an author of intelligence but without much formal education in its subjects; someone who knows the Bible and has learned from the sermons that affected his writing style and from the experience and experiment that affected his contemplations. Highlighting Peckitt's explanation of color may show most clearly the ways that he attempts to take what he understands from practice and hearsay and perhaps from reading as well. The result casts some typical ideas of his time, notably the emphasis on trichromacy and the description of vision, into a new vocabulary without accompanying conceptual changes. He barely explains the formation of secondary colors, or of shades, and tones, offering less in that respect than Jacques-Fabien Gautier d'Agoty or other scientific writers of his time did. Nevertheless, Peckitt's description clarifies the system, down to the incorporation of color, used in his practical work.

This association of fire with color complements Peckitt's colored-glassmaking, as his explanations of attraction and repulsion explain his understanding of the formation of color on glass—especially the flashed glass for which he was famous. Fire melts the coloring materials, causing them to expand and cover the substrate as it forces the different elements of the coloring materials together; they sink into the pores of the substrate as water sinks into earth. Different colors have different degrees of attraction to the substrate. The greater the attraction, the less likely the color is to peel or rub off. As the earth was formed, so is color on glass.

Conclusions

Both George Berg and William Peckitt used glassmaking as the entry point for an extended personal search for enlightenment. In both cases, the search incorporated a direct relation between personal experiment and public life, even if no significant public repercussions took place. The juxtaposition of Peckitt's practical manuscript with his published philosophy makes it clear that his working life was not confined by the walls of his workshop. The order he created there was part of a larger order in the universe. That he could place the colors he uses so neatly into that system may have been serendipitous, but it was also advantageous to him. For Peckitt, the mechanics of work and the mechanics of life are the same, both being a microcosm of the combination of religious belief with physics and chemistry.

George Berg's notebooks provide a picture of a different kind of enlightened man. They demonstrate the pull exerted on the curious by available information. Perhaps better educated in a general sense than Peckitt, Berg also had the advice of many people who knew what he did not. Although he directed his own experiments, he was not the master of his subject. When chemistry entered Berg's workspace, as it did regularly, it was the chemistry legitimized, more directly than Peckitt's, by the enlightened scientific and technological institutions—the Society of Arts and the Royal Society. Berg's trials were not directed toward an explanation and reflection on a life's work, but this is an inherent difference between an experiment book and a manual, published or not. Together, these books—manuscript or printed—amplify the reasons why color was a good subject through which to explore the world. They remind us of opportunities within the spheres of artisans, scientists, manufacturers, opportunities that were available simultaneously and that were taken. They suggest that, however close these spheres were, they were not closed.

Notes:

Note 1: William Peckitt to the Society of Arts, 4 February 1760, [[R]SA PR.GE/110/11/8; J. A. Knowles, "William Peckitt, Glass Painter," *The Seventeenth Volume of The Walpole Society* 17 (1927-1928): 45–60; J. T. Brighton, "William Peckitt's Commission Book," *The Fifty Fourth Volume of the Walpole Society* 54 (1988): 334–453; J. T. Brighton, "William Peckitt, 1731–95, and Portraiture on Glass," *Preview (York City Art Gallery Bulletin)* 34, no.125 (1984): 3–11.

Note 2: *York Courant*, 14 July 1752.

Note 3: Brighton, "William Peckitt and Portraiture on Glass."

Note 4: George Berg, *Experiments in Chemistry 1759–1774*, Dudley Archives Centre RBC/7/8/1 (no longer available); Mr. [James] Christie*, A Catalogue of the Valuable and Scarce Collection of Music, by the Most Eminent Composers, Fine Ton'd Instruments, Books &c, Late the Property of Mr George Berg, Dec*, 8–9 March 1776 (London, 1776).

Note 5: R.G. Newton, J. T. Brighton, and J. R. Taylor, "An Interpretation of Peckitt's Eighteenth Century Treatise on Making Glasses and the Stains for Them," *Glass Technology* 30 (1989): 33–38; R G. Newton and J. R. Taylor, "Peckitt's Eighteenth Century Treatise: Staining Glass with Red Tones," *Glass Technology* 31 (1990): 69–71; W. A. Campbell, "Musical Glasses," *Chemistry in Britain* 25, no.2 (1989): 145–48.

Note 6: Edward Hussey Delaval, *A Letter the Right Honourable The Earl of Morton, President of the Royal Society Containing Experiments and Observations on the Agreement between the Specific Gravities of the Several Metals, and Their Colours . . . Read at the Royal Society Jan 24 1765* (London, 1765).

Note 7: Campbell, "Musical Glasses," 147.

Note 8: Wolf Mankowitz, *The Portland Vase and the Wedgwood Copies* ([London, 1952]); Robin Reilly, "Josiah Wedgwood, A Lifetime of Achievement," in *The Genius of Wedgwood*, ed. Hilary Young (London, 1995), 54; see also David B. Whitehouse, ed., "The Portland Vase," *Journal of Glass Studies* 32 (1990): 14–188 and also "The Portland Vase," at The Wedgwood Museum website (http://www.wedgwoodmuseum.org.uk/portland_vase.htm).

Note 9: Berg, [paper bound into Notebook 5 dated 21 November 1771], *Experiments in*

Chemistry 1759–1774.

Note 10: "The Method of Dying Silk, Wool, or Cotton with Cudbear," 26 May 1761, [R]SA PR.GE/110/11/43; Committee Minutes for the Chemistry Committee, 11 June 1761 and 18–25 June 1761, [R]SA Minutes of Various Premium Committees 1761–62, [R]SA PR.GE/112/12/3; Committee Minutes for the Chemistry Committee, 4 December 1761, 16 January 1762, and 13 February 1762, [R]SA Minutes of Various Premium Committees 1761–62, [R]SA PR.GE/112/12/3.

Note 11: Ephraim Chambers, *Cyclopaedia; or, An Universal Dictionary of Arts and Sciences Containing an Explication of the Terms and an Account of the Things Signified Thereby in the Several Arts, Both Liberal and Mechanical, and the Several Sciences, Human and Divine, the Figures, Kinds, Properties, Productions, Preparations and Uses of Things Natural and Artificial: The Rise, Progress and State of Things Ecclesiastical, Civil, Military, and Commercial: With the Several Systems, Sects, Opinions, &c. among Philosophers, Divines, Mathematicians, Physicians, Antiquaries, Critics, &c.: The Whole Intended as a Course of Antient and Modern Learning: Extracted from the Best Authors, Dictionaries, Journals, Memoirs, Transactions, Ephemerides, &c. in Several Languages* (London, 1778–88).

Note 12: Campbell, "Musical Glasses," 147.

Note 13: Ibid., 148.

Note 14: William Peckitt, *The Principals [sic] of Introduction into That Rare but Fine and Elegant Art of Painting and Staining of Glass* (1793), York Museums Trust (York Art Gallery) York, England, MS, f 31.

Note 15: William Peckitt to the Society of Arts 4 February 1760 [R]SA PR.GE/110/11/8; Peckitt, *The Principals of . . . Painting and Staining of Glass*.

Note 16: Newton, Brighton, and Taylor, "An Interpretation of Peckitt's Eighteenth Century Treatise on Making Glasses and the Stains for Them," 33.

Note 17: "Composing Stained Glass with Unstained Glass, and Grinding, with Variety of Ornaments, the Various Works Formed of the Same," English Patent no. 1268 issued toWilliam Peckitt, City of York, Glass Painter and Stainer (22 November 1780).

Note 18: [William Peckitt] *The Wonderful Love of God to Men or Heaven Opened in Earth* (York, 1794).

Note 19: Jacques-Fabien Gautier, *Chroa-génésie ou géneration des couleurs contre le système de Newton.* ([Paris], 1749).

Note 20: [Peckitt], *The Wonderful Love of God to Men,* 18.

Note 21: [Peckitt], *The Wonderful Love of God to Men,* 19.

