Humphry Davy's Early Chemical Knowledge, Theory and Experiments: An Edition of his 1798 Manuscript, "An Essay on Heat and the Combinations of Light" from The Royal Institution of Cornwall, Courtney Library, MS DVY/2

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This paper publishes, for the first time, Humphry Davy's June 1798 "An Essay on Heat and the Combinations of Light" written in Penzance. It is the manuscript that he sent to Thomas Beddoes which secured for him the position of Superintendent of the Medical Pneumatic Institution in Bristol while aged only nineteen. It is thus a crucial document that increases our understanding about how Davy made that move from Cornwall to Bristol, without which it is highly unlikely that he would have followed the spectacular career trajectory that he did. The "Essay" provides new insights into Davy's very early chemical reading (especially the English translations of Antoine Fourcroy's *Elémens d'histoire naturelle et de chimie*), the extent to which Davy read this (and other texts) in French, the chemical apparatus he used, the experiments he made and the development and retraction of his theory of phosoxyd (later phosoxygen).

Introduction

The well-known move that Humphry Davy (1778-1829) made in October 1798 at the age of nineteen from serving an apprenticeship with the Penzance surgeon and apothecary John Borlase (1753-1813) to being Superintendent of the Medical Pneumatic Institution in Bristol was facilitated both by his social connections and by the promise he showed in chemical investigation. His social links, including Davies Giddy (Gilbert from December 1817, 1767-1839), a minor member of the West Cornwall gentry, Gregory Watt (1777-1804) and Tom Wedgwood (1771-1805), sons of prominent Midland industrialists who had wintered in

Penzance over 1797/8 for the sake of their health, have been well documented.[1] More than thirty years later James Watt jr (1769-1848) recollected that his younger half-brother Gregory, who had lodged with Davy's mother, "was pleased with his [Davy's] talents and disposition and took pains to direct his studies ... and spoke of him among his friends as an extraordinary young man".[2]

All three were closely connected with the radical (Jacobin) physician Thomas Beddoes (1760-1808) who since 1794 had been raising funds to establish the Medical Pneumatic Institution to investigate the possible therapeutic effects of all the gases that had been discovered during the eighteenth century by savants such as Joseph Priestley (1733-1804) and Joseph Black (1728-1799). In 1798 Beddoes believed that he had secured enough support to open the Institution and so now required a Superintendent to take charge.[3] Giddy explicitly recommended Davy to Beddoes, in which he was supported, at the very least implicitly, by Gregory Watt, and probably by Wedgwood (though direct evidence is lacking there). However, it would seem unlikely that Beddoes would have offered Davy the position were it not for the manuscript chemical essay, published here, that Davy sent him in June that year.[4] This "Essay" is thus a key document in understanding how Davy made that crucial move from Penzance to Bristol, without which it would have been highly unlikely that the rest of Davy's spectacular career trajectory could have occurred. Although Jan Golinski has recently illustrated how Davy self-constructed his image from his time in Bristol onwards to meet various cultural and social expectations, he did not discuss the contingencies of Davy's early years which allowed him that opportunity, devoting only a couple of pages to Davy's life in West Cornwall.[5] What emerges from this "Essay" is that some of the features that Golinski identified in Davy's later career were already present in

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[1] For example, David Knight, *Humphry Davy: Science and Power* (Oxford: Blackwell / Cambridge: Cambridge University Press, 1992/1996) and June Z. Fullmer, *Young Humphry Davy: The Making of an Experimental Chemist* (Philadelphia: American Philosophical Society, 2000).

[2] James Watt jr to John Craig, 24 September 1831, Royal Institution (hereafter RI) MS HD/26/D/67.

[3] Frank A.J.L. James, *'the first example … of an extensive scheme of pure scientific medical investigation': Thomas Beddoes and the Medical Pneumatic Institution in Bristol, 1794 to 1799* (London: Royal Society of Chemistry Historical Group Occasional Papers No. 8, 2016), 34.

[4] Humphry Davy, "An Essay on Heat and the Combinations of Light," The Royal Institution of Cornwall, Courtney Library, (hereafter RIC) MS DVY/2. This will be cited as Davy, "Essay" MS; pagination will refer to the MS.

[5] Jan Golinski, *The Experimental Self: Humphry Davy and the Making of a Man of Science* (Chicago: University of Chicago Press, 2016), 20-21.

the nineteen year old Davy, especially his ability to tailor his writings for a specific audience, in this case Beddoes.

Until now our understanding of Davy's early chemical views has stemmed from his first two published papers which appeared in early 1799 in Beddoes's *Contributions to Physical and Medical Knowledge, Principally from the West of England and Wales* which Davy, at Beddoes's request, saw through the press. These two essays ran to just over 29,000 words and comprised more than a third of *Contributions*.[6] They were based on this June 1798 manuscript of Davy's published here, a document containing just over 16,000 words. It seems not to have been used before (it is not cited in the recentish biographies by either Knight or Fullmer[7]), but it provides new insights into Davy's earliest chemical knowledge and investigations.[8] While I am focussing this introduction on what Davy knew about chemistry by June 1798, comparison of the manuscript with the published text also casts light on what he learned and read in the following months (to mid-February 1799), including after his arrival in Bristol when he came under Beddoes's direct influence.

In August 1799 Davy recorded in a notebook that he had started studying chemistry "About 20 months ago" that is in November or, more probably, December 1797,[9] doubtless inspired to this by his new friends Watt and Wedgwood. In the same passage he noted that "all my chemical information was derived from Nicholsons Chemistry & Lavoisiers elements".[10] The latter text was the *Traité élémentaire de chimie* (1789; second edition, 1793; English translation, 1790) by Antoine Laurent Lavoisier (1743-1794). Following the

[6] Humphry Davy, "An Essay on Heat, Light, and the Combinations of Light," in *Contributions to Physical and Medical Knowledge, Principally from the West of England*, ed. Thomas Beddoes (London: Longman, printed Bristol, by Biggs and Cottle, 1799), 5-147 and "An Essay On the Generation of Phosoxygen (Oxygen Gas) And on the Causes of the Colors of Organic Beings" in *Contributions to Physical and Medical Knowledge*, 151-205. These will be cited respectively as Davy, "Heat, Light, and the Combinations of Light" and Davy, "Generation of Phosoxygen."

[7] Knight *Humphry Davy*; Fullmer, *Young Humphry Davy*. Indeed, I only located the manuscript by pursuing the clue given in the reference cited in note 103. However, since then Angela Broome, "The Courtney Library, 1818-2018," *Journal of the Royal Institution of Cornwall*, 2018, 151-173 on 153 has referred to it in a special issue of the *Journal* marking the bicentenary of the Royal Institution of Cornwall.

[8] Fullmer, *Young Humphry Davy* sought (58, 68-9) to reconstruct some of Davy's pre-Bristol researches from a reading of his 1799 publications.

[9] RI MS HD/20/B, 186.

[10] RI MS HD/20/B, 190.

lead of John Davy (1790-1868) in his 1836 biography of his elder brother,[11] biographers and historians have presumed that the former text was the two volume *A Dictionary of Chemistry* (1795) by the English chemist and journalist William Nicholson (1753-1815).[12] However, John Davy, who would have been seven and a half when Watt and Wedgwood arrived in Penzance, admitted that of Davy's early chemical studies, "I regret to say that I have very little information to give respecting them"[13] and did not know about the existence of this manuscript "Essay". He did, however, possess Davy's 1799 notebook from which he quoted the passage about what Davy read, though he inserted "Dictionary" between "Nicholsons" and "Chemistry".[14] So, with equal plausibility, the text that Davy read by Nicholson could have been his *The First Principles of Chemistry* (1790, second edition, 1792, third 1796).[15]

Until now, historians and biographers would have had very little evidence which would have enabled the construction of a plausible argument to decide any conjecture as to which text of Nicholson's Davy read, or for that matter determining what other chemical texts and knowledge Davy may have had access to while in Cornwall. This "Essay" provides evidence about at least some of texts Davy read, though much of this has to be interpreted with caution. Nicholson in his *Dictionary*, noted the change of position that the Irish chemist Richard Kirwan (1733-1812) made from suggesting that phlogiston was hydrogen to abandoning phlogiston altogether;[16] in his *First Principles* Nicholson did not refer to Kirwan's change.[17] Davy in this "Essay" referred only to Kirwan holding the view that phlogiston was hydrogen and not mentioning his change of view.[18] That suggests, to some extent at least, that Davy may have read Nicholson's *First Principles* rather than his *Dictionary*.

[11] For the history of this text and of the materials from which it was constructed see Frank A.J.L. James, "Constructing Humphry Davy's Biographical Image," *Ambix* 66 (2019): 214-38.

[12] John Davy, *Memoirs of the Life of Sir Humphry Davy, Bart.*, 2 vols. (London: Longman, 1836), Vol. 1, 42; Knight *Humphry Davy*, 20; Fullmer, *Young Humphry Davy*, 46-61.

[13] John Davy, *Memoirs*, Vol. 1, 42.

[14] RI MS HD/20/B, 190. John Davy, *Memoirs*, Vol. 1, 42.

[15] I am grateful to a referee for this valuable suggestion.

[16] William Nicholson, *A Dictionary of Chemistry*, 2 vols. (London: Robinson, 1795), Vol. 2, 641.

[17] William Nicholson, *The First Principles of Chemistry*, (3rd ed., London: Robinson, 1796), 91.

[18] Davy, "Essay" MS, 31. Davy omitted mentioning Kirwan entirely in the published version of his "Essay".

That Davy was unaware of Kirwan's change is further supported by the manuscript showing that Davy read the English translations of *Elémens d'histoire naturelle et de chimie* (second edition, 1786) by the radical (Jacobin) French chemist Antoine François Fourcroy (1755-1809) one of which was made by Nicholson. Published in 1788 Nicholson in his preface referred only to Kirwan's original views,[19] which thus may well have been another source where Davy's knowledge (or lack thereof) originated rather than not reading the *Dictionary* with sufficient care, which would be an alternative, though unlikely, possibility.

Nicholson's translation, as we shall see, was probably the source of much of Davy's initial chemical knowledge. Davy's use of it may well explain the curious elision in his August 1799 notebook entry of reading "Lavoisiers elements" which combined Lavoisier's name with the title of Fourcroy's *Elémens*. Examples of his use of Fourcroy might have included his brief discussion over who had determined the composition of water, Lavoisier or the English natural philosopher Henry Cavendish (1731-1810), whose work Nicholson discussed in his preface.[20] Davy's discussion of the work on fulminating gold by the French chemist Claude Louis Berthollet (1748-1822) may have come from a later (1796) translation of Fourcroy's *Elémens*.[21] It is of course possible that Davy read the original books and papers, but nothing has been found which supports that suggestion and it does seem to me at least, on the balance of probabilities, a bit unlikely.

Davy's use of Fourcroy also casts light on whether he also read these texts in French. Both John Davy and John Ayrton Paris (1785-1856), Davy's first biographer, noted that from the start of his apprenticeship in 1795 he studied French with a refugee from the Revolution;[22] he also had a French girlfriend which would doubtless have been an inducement, and for whom he allegedly wrote poems in French, only one of which may have

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[19] Antoine François Fourcroy, *Elements of Natural History and of Chemistry*, [trans. William Nicholson], 4 vols. (London: Robinson, 1788), Vol. 1, vii.

[20] Davy, "Essay" MS, 29. Fourcroy, *Elements of Natural History*, Vol. 1, xi-xvi. For a discussion of Nicholson's role in the controversy see David Philip Miller *Discovering Water: James Watt, Henry Cavendish and the Nineteenth-Century 'Water Controversy'* (Aldershot: Ashgate, 2004), 62-3. Davy's reference to Cavendish was omitted in Davy, "Heat, Light, and the Combinations of Light," 62 – possibly due to his not supporting Beddoes's fundraising efforts, James, *'the first example …'*, 21-2.

[21] Davy, "Essay" MS, 49-50; Antoine François Fourcroy, *Elements of Chemistry and Natural History to which is prefixed the Philosophy of Chemistry*, trans. Robert Heron, 4 vols. (London: Murray and Highly, 1796), Vol. 3, 147-8.

[22] John Davy, *Memoirs*, Vol. 1, 21; John Ayrton Paris, *The Life of Sir Humphry Davy, Bart.*, 2 vols. (London: Colburn and Bentley, 1831), Vol. 1, 16.

survived.[23] Early in the manuscript Davy quoted briefly from Lavoisier's *Traité*[24] and later referred to "Traite elementaire Tom. premier" in connection to Lavoisier's proof of the composition of water.[25] It is, therefore, entirely possible that Davy read the *Traité* in French. On the other hand, in mentioning Fourcroy's *Elémens* Davy referred to "Tom 1, p 96"[26] which would be read naturally as a referring to one of the French editions; however, it was actually to the 1796 English translation.[27] And in his August 1799 notebook, Davy used the English word "elements" as the title for Lavosier's and/or Fourcroy's work(s).

In whatever language Davy read Lavoisier and Fourcroy he would have found that they opposed the previously prevailing chemical theory based on the idea of phlogiston formulated originally by Georg Ernst Stahl (1659-1734). Furthermore, Lavoisier had developed a new chemical nomenclature introducing terms, still in use, such as oxygen, hydrogen and so on. Although using this nomenclature meant that discussing chemical theory in terms of phlogiston became difficult, getting rid of it altogether was by no means straightforward. Lavoisier in effect had to replace phlogiston with caloric, listing it, along with light (at the top) as "Substances simples" followed by silver, gold, copper, iron etc.[28]

After his early reading it would seem that Davy soon began chemical experimentation.[29] Both Paris (who would have learnt about it from Gilbert who during 1829 and 1830 provided him with significant material for his biography[30]) and John Davy emphasised the very basic nature, mostly domestic, of the equipment Davy initially used.[31]

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[23] Paris, *Life*, Vol. 1, 24 and a recollection by Davy's sister, Katherine Davy, c.1830s, RI MS HD/26/D/79, 2r. Fullmer, *Young Humphry Davy*, 22 quoted the poem from a play performed in Paris in 1854, *La Lampe de Davy ou L'Armour et le Travail* in Christien Ostrowski, *Théatre Complet*, 3rd ed., 2 vols. (Paris: Fermin Didot, 1862), Vol. 1, 277-303, 301. Assuming the poem was by Davy, quite how Ostrowski came across it is not known.

[24] Davy, "Essay" MS, 3.

[25] Davy, "Essay" MS, 29.

[26] Davy, "Essay" MS, 21-2.

[27] Fourcroy, *Elements of Chemistry*, Vol. 1, 98. However, in the printed text Davy, "Heat, Light, and the Combinations of Light," 51 he referenced and quoted the passage in French from Antoine François Fourcroy, *Elémens d'histoire naturelle et de chimie*, 3rd ed., 4 vols. (Paris: Cuchet, 1789), Vol. 1, 126-7.

[28] Antoine Lavoisier, *Traité élémentaire de chimie*, 2 vols. (Paris: Cuchet, 1789), Vol. 1, 192. For further discussion see Hasok Chang, *Is Water H_2O? Evidence, Realism and Pluralism* (Dordrecht: Springer, 2012), especially chapter 1.

[29] John Davy, *Memoirs*, Vol. 1, 43-4.

[30] James, "Constructing Humphry Davy's Biographical Image," 223.

[31] John Davy, *Memoirs*, Vol. 1, 43; Paris, *Life*, Vol. 1, 41.

Items that Davy mentioned in his "Essay" included pasteboard and sheep bladder.[32] Nevertheless, this work contributed towards drawing him to Giddy's notice. Shortly after Davy had departed for Bristol, Giddy told Thomasina Dennis (1770-1800), an aspiring writer whom he taught Greek and Latin,

> I was first introduced to his acquaintance by Mr. John Dennis and never felt myself more surprised on discovering a young man situated in all respects so disadvantageously as Mr. Davy prosecuting experiments and investigations worthy of Doctor Priestl[e]y. I could not but be the more astonished, perfectly remembering his late father[33]

This account (rather uncomplimentary towards Davy's father) agrees well with the much later recollection of Davy's sister Katherine Davy (1781-1860) that Davy showed "Mr John" (by 1835 "one of the oldest inhabitants of Penzance"[34]) some experiments that he had been performing. Dennis did not understand them but offered to introduce Davy to Giddy.[35]

This introduction was made after Gregory Watt had left Penzance for Truro in mid-March 1798[36] since Giddy told him that he only met Davy after that.[37] It proved decisive for Davy since Giddy actively supported talented Cornish people, Dennis being a good example. Thus, Giddy's patronage of Davy was well in line with his normal practice and he gave him access to his library at his house Tredea, a few miles north east of Penzance;[38] he may have also lent him books as he did to Gregory Watt.[39] As a former student of Beddoes at Oxford University and with very strong scientific interests, we may be reasonably sure that Giddy's library would have contained a good collection of recent and contemporary scientific books. Other sources that would have been available to Davy included Borlase's library and those

[32] Davy, "Essay" MS, 23 and 55 respectively. For the prevalence of the chemical use of domestic items see Simon Werrett, *Thrifty Science: Making the Most of Materials in the History of Experiment* (Chicago: Chicago University Press, 2019), especially chapters 2 and 5.

[33] Davies Giddy to Thomasina Dennis, 17 November 1798, Cornwall Record Office (hereafter CRO) DG/87/1/20.

[34] John Davy, *Memoirs*, Vol. 1, 48.

[35] Katherine Davy, Recollection, 4 January 1831, RI MS HD/26/D/79, 3r-v.

[36] Gregory Watt to James Watt sr, 22 March 1798, Library of Birmingham (hereafter LoB) MS 3219/7/49/12, written from Truro.

[37] Davies Giddy to Gregory Watt, 18 July 1798, LoB MS 3219/7/5/54.

[38] Paris, *Life*, Vol. 1, 47. Probably taken from a recollection by Gilbert.

[39] Davies Giddy to Gregory Watt, 20 January 1798, LoB MS 3219/7/5/53.

of other Penzance medics referred to by John Davy,[40] though whether they would have owned the most up to date chemistry texts is open to question. In addition to Giddy's library, another possible source of books were those that Wedgwood, a pupil of the Scottish natural philosopher John Leslie (1766-1832), had brought with him to Penzance,[41] although he moved to London late in January 1798.[42] Whatever his sources Davy in his "Essay," in addition to Fourcroy's *Elements*, referred to other texts. These included the two volume *Zoonomia; or the Laws of Organic Life* (1794-6) by the radical physician and writer Erasmus Darwin (1731-1802) referring to the work of his son Robert Darwin (1766-1848).[43] Davy, without attribution or indication that he was doing so, quoted from *An Inquiry into the Cause of Motion* (1781) by the unidentifiable S. Miller[44] which Augustus De Morgan (1806-1871) later characterised as asserting "Newton all wrong".[45] Davy did this in the context of discussing the "ingenious" ideas of Isaac Newton (1642-1727) on the production of light; Davy's published version quoted from query eight of the *Opticks* and referenced nine and ten.[46] Whether Davy had read the *Opticks* at this point is not clear, but he did refer in the manuscript to the observations of Edmond Halley (1656-1742ns) of the colours he observed when underwater in a diving bell, first noted in the second edition of the *Opticks*.[47] However, it would seem more likely that that Davy would have come across the reference in Nicholson's 1788 translation of Fourcroy.[48]

Not only did Giddy help Davy with his studies, he also introduced him to John Edwards (1731-1807) who managed the Cornish Copper Company at Hayle on the coast to the north east of St Erth.[49] Giddy's surprise at Davy's experimental dexterity probably stemmed, in part at least, from the paucity of apparatus which he initially used, but the

[40] John Davy, *Memoirs*, Vol. 1, 51.

[41] Referred to in Davies Giddy to Gregory Watt, 20 January 1798, LoB MS 3219/7/5/53.

[42] Gregory Watt to James Watt sr, 19 January 1798, LoB MS 3147/3/76/03.

[43] Davy, "Essay" MS, 20 only cited the first volume

[44] Davy, "Essay" MS, 21 (note). S. Miller, *An Inquiry into the Cause of Motion; or, a general theory of physics, grounded upon the primary qualities of matter* (London: The author, 1781), 24-5.

[45] Augustus De Morgan, *A Budget of Paradoxes* (London: Longman, 1872), 100.

[46] Davy, "Heat, Light, and the Combinations of Light," 51 with attribution. Isaac Newton, *Opticks: or, A Treatise of the Reflections, Refractions, Inflections and Colours of Light*, 2nd ed. (London: Innys, 1718) 314-18.

[47] Davy, "Essay" MS, 27. Newton, *Opticks*, 160-1.

[48] Fourcroy, *Elements of Natural History*, Vol. 1, 166. There was no reference to this in the 1796 translation.

[49] On this see W.H. Pascoe, *CCC. The History of the Cornish Copper Company* (Hayle: Haylebooks, 1981).

Company possessed a well-equipped laboratory. There Davy expressed "tumultuous delight on seeing, for the first time, a quantity of chemical apparatus, hitherto only known to him through the medium of engravings".[50] From this point Davy was able to use the kind of apparatus that Lavoisier and others used, such as an air pump[51] (he had hitherto used an old syringe[52]) and a chemical balance, though he was unable to weigh light using this.[53] Assuming he did not begin using such sophisticated apparatus immediately on beginning his chemical studies, he would have had significantly less than eight months (prior to June 1798) in which to undertake the experiments he described in the manuscript and interpret them according to his theoretical ideas, which included the immateriality of heat.

A little while before Benjamin Thompson, Count Rumford (1753-1814), had also concluded, by different experiments, that heat was immaterial. He published his experiments and views in a paper read to the Royal Society of London on 25 January 1798[54] and sent Beddoes an offprint probably in early April. Beddoes told Giddy about Rumford's work, adding that he (Beddoes) had for "some time given up *caloric &* I have thought that the phaenomena are well reducible to vibration".[55] This may well have been the impetus behind the suggestion made, according to Paris, by Giddy to Davy that he should send an account of his experiments to Beddoes.[56] Davy wrote to Beddoes during the second half of April, since Beddoes referred both to Davy and to Rumford in a letter written towards the end of the month. In this Beddoes noted that Davy had offered to send him an account of his experiments.[57] In turn that suggests Davy began writing this "Essay" in late April or early May 1798, though interestingly in it he does not refer to Rumford's work. Indeed, in an

[50] Paris, *Life*, Vol. 1, 47. Probably also taken from a recollection that Gilbert gave Paris.

[51] Davy, "Essay" MS, 3.

[52] Davies Giddy to Gregory Watt, 18 July 1798, LoB MS 3219/7/5/54.

[53] Davy, "Essay" MS, 46 (note).

[54] Rumford, "An Inquiry concerning the Source of the Heat which is excited by Friction," *Philosophical Transactions* 88 (1798) 80-102.

[55] Thomas Beddoes to Davies Giddy, 14 April 1798, CRO DG/42/2.

[56] Paris, *Life*, Vol. 1, 52.

[57] Thomas Beddoes to William Reynolds, nd but late April 1798 in John Stock, *Memoirs of T. Beddoes, M.D., with an analytical account of his writings* (London: John Murray, 1811), 155.

"Addenda" to the published text, Davy made it clear that his experiments "were made long before the publication" of Rumford's paper.[58]

Davy carefully constructed his manuscript "Essay" to engage Beddoes's interest. As might be expected of someone who had worked as an apprentice apothecary for just over three years, Davy's overarching theme was the application of the new chemical knowledge "to the laws of organic existence".[59] The hopes for this, he claimed, had not been realised, except by the "ingenious theories" of Beddoes (a diplomatic reference) and the Swiss-born physician and chemist Christopher Girtanner (1760-1800) who had spent some time in Edinburgh;[60] the latter reference was removed from the printed text.[61] Davy then immediately moved on to contradict Lavoisier's assertion that light was a modification of caloric and to attack the idea that caloric was a material, though imponderable, substance, a theory which Lavoisier used to account for chemical phenomena; the latter would have commended itself to Beddoes, though he generally supported Lavoisierian chemistry.

Using the air pump Davy fired a flintlock in a vacuum to show that light was not produced, contradicting Lavoisier.[62] Explicitly using the *reductio ad absurdum* method (he had been studying Euclid intensively during 1796[63]), Davy also argued against the material existence of caloric itself, by showing that when two pieces of ice were rubbed against each other the friction alone melted them – experiments he performed both within and outwith the air pump.[64] These experiments so impressed Giddy that he recalled them at some length in his Royal Society of London Presidential address following Davy's death.[65]

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[58] Davy, "Generation of Phosoxygen," 199.

[59] Davy, "Essay" MS, 1.

[60] Davy, "Essay" MS, 1. Davy might have come across the translations of Girtanner's work in Thomas Beddoes, *Observations on the nature and cure of calculus, sea scurvy, consumption, catarrh, and fever: together with conjectures upon several other subjects of physiology and pathology* (London: Murray, 1793), 171-268.

[61] Davy, "Heat, Light, and the Combinations of Light," 7.

[62] Davy, "Heat, Light, and the Combinations of Light," 9 where he quoted Lavoisier**,** *Traité*, Vol. 1, 6.

[63] See his notebook, RI MS HD/21/A.

[64] Davy, "Essay" MS, 4-6; Davy, "Heat, Light, and the Combinations of Light," 16-20. Night temperatures for most of March 1798 fell below freezing point in London see "Meteorological Journal," *Philosophical Transactions* 89 (1799) 6-7.

[65] Davies Gilbert, "[Presidential] Address [to the Royal Society of London]," *Philosophical Magazine* 7 (1830): 33-46 on 38.

Davy had shown, to his own satisfaction at least, that light was not a modification of heat, that heat was an immaterial corpuscular vibration and that "Light is demonstrably Matter".[66] As he pointed out this contradicted the view of Leonhard Euler (1707-1783) that light was a wave (in opposition to Newton's projectile theory); Davy's knowledge of Euler may also have come from reading Fourcroy.[67] Davy's interpretation of Lavoisierian theory that oxygen gas was "Oxygen combined with Caloric" could not be sustained if caloric was immaterial. He therefore needed to develop an alternative view and proposed instead that oxygen gas was "a substance compounded of Light and Oxygen" which he named "Phosoxyd," an "unexceptionable" term he thought.[68] To support this theory Davy deployed the views of Pierre-Joseph Macquer (1718-1784) who identified light with phlogiston,[69] which he may well, once again, have derived from reading Fourcroy.[70] Davy in effect displaced Lavoisier's caloric with light, but, as the manuscript shows, he pursued the physical, biological, medical and chemical logic of this change. So far as the latter was concerned Davy described many experiments interpreting them as supporting his phosoxyd theory.

As to the physical, biological and medical implications of his theory, Davy devoted the last dozen or so pages of his "Essay" to drawing them out, starting with the theory of respiration, again suggesting how carefully he tailored his work to appeal to Beddoes. The overall thrust of his argument was the essentialness of light and phosoxyd to all forms of life, from lettuces, fish and animals, to, of course, humans. The amount of light and phosoxyd to which an individual was exposed, Davy argued, would account for diverse skin colours, gender differences as well as the state of civilisation in different parts of the globe.[71] These views precisely echoed Beddoes in his *Alexander's Expedition* of 1792[72] and doubtless contributed to the formation of Davy's opinion of the racial superiority of white

[66] Davy, "Essay" MS, 4.

[67] Davy, "Essay" MS, 3. Fourcroy, *Elements of Chemistry*, Vol. 2, 272.

[68] Davy, "Essay" MS, 18 where he also gave the derivation of the term from the Greek, illustrating what he had learnt from his year attending Truro Grammar School in 1793.

[69] Davy, "Essay" MS, notes to 2, 21, 31.

[70] Fourcroy, *Elements of Natural History*, Vol. 1, 134.

[71] Davy, "Essay" MS, 60-3.

[72] [Thomas Beddoes], *Alexander's Expedition Down the Hydaspes & the Indus to the Indian Ocean* (London, Murray, 1792), 80.

Europeans.[73] His theory would account for the excellence of air near coasts that had been asserted by Jan Ingen-Housz (1730-1799).[74] Furthermore, it would explain the action of planetary atmospheres as well as the solar atmosphere discovered by Giovanni Domenico Cassini (1625-1712).[75] Davy concluded with a peroration commencing "Science is as yet in her infancy," a trope that would recur frequently in his future writings.[76] He ended with a passage predicting that scientific knowledge would free humankind from "Despotism & superstition" thus ensuring that it would "never [be] separated from the happiness of Mankind".[77]

Beddoes later recollected that he received Davy's "Essay" in April,[78] but this must refer to his earliest correspondence with Davy.[79] According to Paris, Davy's manuscript was taken to Bristol by Gregory Watt on his way from Truro to Birmingham in mid-June 1798.[80] Watt had returned to the Penzance area at the end of May dining with Giddy at Tredea then.[81] So, it is at least possible that Watt also met Davy while near Penzance and took possession of the manuscript then or very shortly thereafter. Such a deadline would also explain why Davy in the "Essay" did not discuss his early work, begun in May 1798,[82] on the physiological properties of nitrous oxide, though he did discuss its chemistry.[83] Towards its end, the manuscript does show some signs of haste. Davy once indicated a footnote that he

[73] See Thomas Moore's diary entry for 24 March 1824 in John Russell, ed., *Memoirs, Journal, and Correspondence of Thomas Moore*, 8 vols, (London: Longman, 1853-1856), Vol. 4, 172.

[74] Davy, "Essay" MS, 45. Jan Ingen-Housz, "On the Degree of Salubrity of the common Air at Sea, compared with that of the Sea-shore, and that of Places far removed from the Sea," *Philosophical Transactions* 70 (1780): 354-377.

[75] Davy, "Essay" MS, note to 57.

[76] Davy, "Essay" MS, 64. For a brief discussion see Frank A.J.L. James and Sharon Ruston, "New Studies on Humphry Davy: Introduction," *Ambix* 66 (2019): 95-102 on 99.

[77] Davy, "Essay" MS, 64.

[78] This date of its receipt was given in Thomas Beddoes, "Specimen of an Arrangement of Bodies according to their Principles" in Beddoes, ed., *Contributions*, 207-230 on 212.

[79] Thomas Beddoes to William Reynolds, nd but late April 1798 in Stock, *Memoirs of T. Beddoes*, 155.

[80] Paris, *Life*, Vol. 1, 52, another story that that Paris probably received from Gilbert. Gregory Watt to Boulton & Watt, 12 June 1798, LoB MS 3147/3/76/11 written from Truro, noted he was about to depart for Birmingham. That Watt called on Beddoes on his way to the Midlands is evident from Thomas Beddoes to James Watt sr, 15 July 1798, LoB MS 3219/4/29/32 discussing Davy's appointment to the Medical Pneumatic Institution. The chronology of these events given in Fullmer, *Young Humphry Davy*, 88 is incorrect.

[81] Giddy, *Diary*, 31 May 1798, CRO DG/16 (no pagination).

[82] Which Davy noted in RI MS HD/20/A, 201.

[83] Davy, "Essay" MS, 42, 47, 48 (note) and 51.

did not write and twice noted "Mem[orandum]," once referring to Darwin and once to the notion of shame, but added nothing further, suggesting the possible need to complete it to a deadline.[84]

Beddoes was enormously impressed with Davy's "Essay" writing to Giddy and to James Watt sr (1736-1819) to tell them so. To the latter he wrote "I have read the acct of some expts of his; & he appears to me to have uncommon talents for philosophical investigations".[85] It is little wonder after reading Davy's "Essay" together with the recommendations of Giddy, Gregory Watt and possibly Wedgwood, that Beddoes, despite having never met him, began in July to discuss with Giddy the practicalities of Davy moving to Bristol to superintend the Medical Pneumatic Institution,[86] which duly happened in October.

Davy spent four months with Beddoes before publication of his two papers based on this "Essay" in *Contributions*. As I have noted during this introduction some of what he wrote in his "Essay" did not appear in the published texts. As Davy told his Penzance friend, the physician Henry Penneck (1761-1834) "My nomenclature is nearly the same as that of the paper you read at Penzance & this is the only part of the work that is similar."[87] Davy in the published texts had replaced the word "phosoxyd" with "phosoxygen" (by which he meant oxygen combined with light) and reserved the former term to refer to what we now call oxides. He also added references to the work of figures such as Black and the geologist James Hutton (1726-1797), both of whom Beddoes had known when at Edinburgh University, as well as Wedgwood[88] and discussed various experiments he had undertaken following his move to Bristol, for example his work on strontian with William Clayfield (1772-1837).[89]

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[84] Davy, "Essay" MS, 62, 57 and 61 respectively.

[85] Thomas Beddoes to James Watt sr, 15 July 1798, LoB MS 3219/4/29/32.

[86] Thomas Beddoes to Davies Giddy, 4 July 1798, Paris, *Life*, Vol. 1, 53.

[87] Humphry Davy to Henry Penneck, 26 January 1799, in *The Collected Letters of Sir Humphry Davy*, ed. Tim Fulford and Sharon Ruston, advisory ed. Jan Golinski, Frank A.J.L. James and David Knight, 4 vols. (Oxford: Oxford University Press, 2020), Vol. 1, letter 9 (hereafter cited as Davy, *Collected Letters* followed by volume and letter number).

[88] Davy, "Heat, Light, and the Combinations of Light," 6, 13, 109 (Black), 64 (Hutton), 55-6 (Wedgwood).

[89] Davy, "Heat, Light, and the Combinations of Light," 111-12.

Beddoes delayed publishing *Contributions*, since even in early March he still expected to receive a couple of further papers to complete the volume.[90] So Davy, in a youthful rush for publication, in mid-February had a few separate copies of his own papers printed off.[91] He promised copies to his relations and friends in Penzance as well as to the library there[92] and asked Penneck to critique it.[93] Although we don't have Penneck's views, we do have Giddy's of whom Davy made the same request.[94] These were contained in a letter to Dennis:

> They prove him to be a very wonderful young man. Theories are pushed too far, as might be naturally expected, and the words 'clearly proved', 'demonstrated', 'evident' etc. Composed with the enthusiasm of a young Philosopher – yet I really believe Chemistry will date a new era from the labours of a young man under twenty at Penzance[95]

It is possible that Giddy sent Davy something similar since he acknowledged his "excellent and truly philosophic observations [which] will induce me to pay greater attention to all my positions."[96]

Probably as early as the second half of April Davy had come to agree with Giddy's view. In mid-April Davy discovered at the Medical Pneumatic Institution the remarkable physiological properties of nitrous oxide, which he quickly appreciated were important. His final printed use of the term "phosoxygen" was in a letter to Nicholson's *Journal*, dated 11 April 1799 and of "phosoxyd" in a note six days later to the same publication.[97] Early the following year he publicly declared, again in the same journal and without using either term, "I beg to be considered as a sceptic with regard to my own particular theory of the

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[90] Thomas Beddoes to Davies Giddy, 5 March 1799, CRO MS DG/42/12.

[91] COPAC notes the existence of just five copies throughout the world. Accessed 27 May 2019.

[92] Humphry Davy to Henry Penneck, 26 January 1799, Davy, *Collected Letters*, Vol. 1, letter 9; Humphry Davy to Grace Davy, 18 January 1799, Davy, *Collected Letters*, Vol. 1, letter 7.

[93] Humphry Davy to Henry Penneck, 26 January 1799, Davy, *Collected Letters*, Vol. 1, letter 9.

[94] Humphry Davy to Davies Giddy, 22 February 1799, Davy, *Collected Letters*, Vol. 1, letter 10.

[95] Davies Giddy to Thomasina Dennis, 28 February 1799, CRO MS DG/87/1/25.

[96] Humphry Davy to Davies Giddy, 18 April 1799 Davy, *Collected Letters*, Vol. 1, letter 14.

[97] Respectively Humphry Davy, "Letter … introductory to the Experiments contained in the subsequent Article, and on other Subjects relative to the Progress of Science," *A Journal of Natural Philosophy, Chemistry and the Arts* 3 (1799): 55-6 and "Extract of a Letter," *A Journal of Natural Philosophy, Chemistry, and the Arts* 3 (1799): 93.

combinations of light and theories of light in general."[98] In the privacy of his notebooks Davy both chastised and justified himself: "I was perhaps wrong in publishing with such haste a new Theory of chemistry & my mind was ardent & enthusiastic, I believed I had discovered the truth".[99] He seems to have realised that his essays might have the potential to distract from his major discovery and so sought to distance himself from his earlier "enthusiasm of a young Philosopher." It was probably this motive that led him, according to John Davy, to tell Thomas Hope (1766-1844), Black's successor as Professor of Chemistry at Edinburgh University, when he visited Bristol that year that "he would joyfully relinquish any little glory or reputation which he might have acquired by his later researches, were it possible to withdraw these essays."[100] Nevertheless, John Davy provided a defence of his elder brother's early views.[101]

What happened to the manuscript immediately after the publication of Davy's work in *Contributions* is not completely clear. It would appear that the manuscript returned to his possession since at the beginning he wrote in large letters on three lines taking up the entire page, "Humphry Davy | Hum | Hum" and at the end attempted to draft a poem; it is hard to credit that these jottings would have been originally included in such an important document. In the early 1830s Borlase's part of Davy's apprenticeship indenture had somehow come into the possession of the Penzance-born lawyer and geologist Richard Edmonds (1801-1886)[102] who by 1870 also possessed Davy's "Essay" manuscript.[103] There is a documented link between Edmonds and Davy. As noted above Davy had shown the "Essay" to his Penzance friend Penneck before sending it to Beddoes, so it would be well within the bounds of plausibility that Davy later gave him the manuscript. Following Penneck's death in 1834 Edmonds became one of the trustees of the estate of his son, the

[98] Humphry Davy, "on the Nitrous Oxide, or Gaseous Oxide of Azote, on certain Facts relating to Heat and Light, and on the Discovery of the Decomposition of the Carbonate and Sulphate of Ammoniac," *A Journal of Natural Philosophy, Chemistry, and the Arts* 3 (1799): 515-18 on 517.

[99] RI MS HD/20/B, 188. Probably written in August 1799.

[100] John Davy, *Memoirs*, Vol. 1, 80.

[101] John Davy, *Memoirs*, Vol. 1, 80-84.

[102] RIC MS DVY/1 (Davy's half is in RI MS HD/5/3); Edmonds's possession of the indenture is referred to in Paris, *Life*, Vol. 1, 14.

[103] George Clement Boase and William Prideaux Courtney, *Bibliotheca Cornubiensis: A Catalogue of the Writings, Both Manuscript and Printed, of Cornishmen, and of Works Relating to the County of Cornwall With Biographical Memoranda and Copious Literary References*, 3 vols. (London: Longman, 1874-1882), Vol. 1, 108.

clergyman Henry Penneck (1800-1862).[104] At some point following Edmonds's death and before 1929 both documents were transferred to the Royal Institution of Cornwall in Truro where they remain.[105]

For historians and biographers, the value of this "Essay" is that it provides a firmly dated insight into the chemical knowledge, practices and ideas that the nineteen-year-old Davy possessed before he properly began to construct his career in science. It also illustrates the kind of knowledge that could be accessed in late eighteenth-century Cornwall and how experimentation, at least at the beginning, could be undertaken using familiar, easily obtainable, objects. However, though his disavowal of the views it contained suggests that he might not have realised it, the chief value of this manuscript for Davy, was that to all intents and purposes it formed a carefully crafted and successful job application.

[104] Edmonds's will in the Principal Registry of the High Court.

[105] The earliest record that the "Essay" was in the possession of the Royal Institution of Cornwall is in 1929 when it was lent to the Royal Geological Society of Cornwall for their commemoration of the centenary of Davy's death, but it is highly likely that it had been in the Royal Institution of Cornwall for some time before then. Private communication from Angela Broome.

The Text

Editorial conventions:

The usual conventions for editing manuscripts have been adopted that is <text interpolated by Davy>, ~~text deleted by Davy,~~ [editorial insertions] and DAVY'S INTENTIONAL EMPHASES ARE THUS INDICATED. The original pagination of the "Essay" has been retained. The line length on the printed page does not relate to the manuscript, though paragraphing has been retained. Davy provided more than fifty notes to this "Essay" usually using the same symbol (a x or + with dots in each quarter, sometimes two together), so, for the sake of clarity, each note has been separately numbered in sequence (if it runs over a manuscript page, this is indicated by the insertion of the page number in bold, without square brackets). As all the texts and all the individuals referred to by Davy in the "Essay" have been identified in the Introduction, no further information is given here.

Note on units: The only quantities that Davy's records in the "Essay" are temperature, measured in °F, and distance, measured in inches and miles. To convert °F to °C subtract 32 and then multiply by 5/9. One inch = 2.54cm and one mile = 1.6km.

The Manuscript

[i blank page]

[ii] **Humphry Davy**

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[iii-v blank pages]

[1] **An Essay on Heat**

and the Combinations of Light.

A DESIRE OF IMPROVEMENT and a peculiar Spirit of Philosophical Investigation, productive of the greatest discoveries in Science and experimental Philosophy, have eminently characterised this Century.-

Chemistry which arose from the ruins of Alchemy, to be bound in the fetters of Phlogiston, has been liberated and adorned with a beautiful philosophic Theory.

The numerous Discoveries of Priestl[e]y, Lavoisier and the other European Philosophers in this branch of Science afford splendid proofs of the increasing energies of the Human Mind. From the application of Chemistry to the laws of organic existence, Mankind had hoped to derive the greatest advantages: from this source they expected the perfection of Medical and Physiological Science; but their hopes have been in great measure frustrated. And if we except Dr Beddoes's and Girtanners ingenious theories

2 We shall find, that Chemistry has as yet afforded but little assistance in the cure of diseases, or in the explanation of the laws of organic Life. ----

The present Imperfection of medicine arises in a great measure from our ignorance of the changes which take place in the animal Oeconomy. An Investigation of the composition of Organic Matter, & of the doctrine of caloric would much elucidate those changes of the animal Oeconomy now unknown & will produce the most beneficial effect on medicine & Physiology, Sciences of the utmost importance to Man, Sciences from the perfection of which He may hope to eradicate a great portion of his physical & moral evil. ---

LIGHT[1] has been heretofore little considered in chemical Theory, its affinities have never been investigated. A Substance of the greatest importance to organic existence has been very little considered but in a physical light as a stimulus, and as the source of the most numerous and pleasurable of our sensations. The beautiful Phænomona, the planetary motions and the laws by

3 which those motions are governed appear to be designed for the express purpose of supplying the whole of the Solar System with a certain necessary quantity of Light. --

[1] Except by Macquer, who I believe substituted it for Phlogiston.

The general Analogy of Nature the wonderful Simplicity of causes and complexity of effects would alone tend to prove that this substance is subservient to other purposes than those of vision and vegetation. ---

Since Light and Heat are usually concomitant, since there is rarely a considerable degree of one without the other, Philosophers have questioned whether they are not cause and effect, and M. Lavoisier is one of these philosophers.

He says. La lumiere, est elle une modification du calorique, ou bien le calorique est il une modification de la lumiere![2]

I have made an Experiment which proves directly that Light is not a modification or an effect of Heat. ---

EXPERIMENT 1ST. A small Gun Cock armed with an excellent flint was several times snapped in the exhausted receiver by means of a peculiar apps; but no Light was produced. The Cock was afterwards snapped in the receiver filled with carbonic acid Gas. The result was the same as before no Light was produced.[3] Small globules were separated

4 from the steel. They were examined by the microscope and had evidently been in a state of fusion. If Light was a modification or an effect of Heat, it must evidently have been produced in this experiment, since the Heat generated by collision was sufficient to fuse steel, a degree of heat much above that improperly called a white heat. Light then is not an effect of Heat. Light is demonstrably Matter. Like other material bodies it is extended and perceptible to the senses. It is emminently [sic] elastic, liable to the chemical laws and those of Attraction. ---

Considering Light as matter it will not be difficult to prove that Heat is a motion, probably a vibration of the Corpuscles of bodies. The existence of Caloric or the matter of Heat has been almost generally believed by the chemical philosophers. We will first attempt to demonstrate its non existence ---

HEAT is not MATTER.

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[2] Lavoisier Traité elementaire. Tom premier. p 6 -

[3] This confutes directly the great Euler's opinion.

Without considering its effects upon bodies, or attempting to prove from these effects that it is motion I shall attempt to demonstrate by exp^{ts}. that it is not Matter. And doing this I shall use the method called by Mathematicians Reductio ad absurdum. ---

5 Let Heat be considered as Matter – Heat or this Matter is continually collected both by friction and percussion. Now since the temperature of bodies is increased by friction & percussion it must be increased in one of these modes ---

First. From the decomposition of the Oxygen Gas in contact which Gas the Calorists assume to be oxygen combined with caloric ---

Secondly. Or from the diminution of the capacities of the acting bodies, from some changes induced in them by the motion, a change inducing them to give out heat.

Thirdly, Or from a collection of Heat by friction & percussion from the bodies in contact.

To demonstrate that the increase of temperature gained by bodies in collision does not arise from the decomposition of the Oxygen Gas in contact or from a diminution of capacity I made the following exp^{ts}. --

Experiment 2^{d}. I procured a piece of clock work so constructed as to be set to work in the exhausted receiver. One of the external wheels of this Machine came in contact with a thin metallic plate. When the machine worked in the open air a considerable degree of Heat was produced by the collision between the wheel & plate. Let this Heat be supposed to arise from the decomposition of Oxygen Gas – The metallic plate was now covered with wax & the machine was placed

6 under the receiver which was exhausted and the machine set to work. The rapid melting of the wax proved the increase of temperature. Heat then was collected by the friction and there was no Oxygen Gas in contact to decompose. It is then evident that the Heat generated by friction cannot arise from the decomposition of Oxygen Gas. ---

Let the heat produced by friction and percussion be supposed to arise from the diminution of the capacities of the acting bodies. Then it is evident that Friction must induce some change in bodies which lessens their capacities and causes them to give out Heat Exp^{t} 3^{d}. Two pieces of ice rubbed together are converted into water. Now according to the supposition Friction diminishes the capacities of bodies; but it is well known that the

capacity of water for Heat is to that of ice as 10 to 9. It is then absurd to suppose that Friction or percussion diminishes the capacities of bodies. ---

Since Heat cannot arise from the Oxydation or diminution of the capacities of the acting bodies, it must if it be considered as Matter, be collected from the bodies in contact, when produced by friction or percussion. ------

Let it be considered as Matter collected by friction from the bodies in contact. EXPERIMENT 4th. I procured a small piece of ice; round the superior edge of this a superficial Canal was made and filled with water. The same machine as I made use of in my second Expt.

7 was placed on the ice; but not in contact with the water.---

Thus disposed the whole was placed in the receiver; which was exhausted and the machine set to work. The wax rapidly melting proved the increase of temperature.---

Caloric then was collected by the friction. Which caloric came from the bodies in contact with the machine; but there was no body in contact with the machine but ice. ---

Had this ice given out Heat the water on the top of it must have been frozen. The water on the top of it was not frozen consequently the ice did not give out Heat. The Heat could not come from the bodies in contact with ice for it must have passed thro' the ice to penetrate the machine and an addition of Heat to the ice would have converted it into water. ---

Heat then when produced by friction cannot be collect from the bodies in contact, and it was proved by the 2d & 3d expts that it cannot arise from the Oxydation or diminution of the capacities of the acting bodies: But if it be considered as matter it must be produced in one of these modes. ---

It is demonstrated by the 2d, 3d & 4th expts that it is not produced in either of these modes. It is consequently not MATTER. --- Since it is produced by motion We have every reason to supposed that it is motion. ---

8 [4]Heat then may be defined a peculiar motion, probably a vibration of the corpuscles of bodies. Those corpuscles are so minute that their motions are imperceptible to sight, but

[4] Heat in common Language signifies that sensation which accompanies an increase of corpuscular motion in any part of our system. It should not therefore be used for the corpuscular motion or cause of that sensation. The Caloric of the French Nomenclators is equally exceptionable. For having been generally used to signify the imaginary fluid or matter of Heat it is now associated with & generally suggests that idea & would thus if used to express the corpuscular motion be a source of error. -- Words expressing compound ideas should when optionally form'd express as near as possible the component parts of the idea, when these component parts

that is no argument for the nonexistence of those motions. We cannot often perceive those vibration of the parts of bodies, which generating undulations in the air are the cause of our sensations of sound. If we cannot even perceive vibrations of the parts of bodies, we cannot expect to see motions of their corpuscles or minutest indivisible atoms. ---

Changes are produced in bodies in proportion as their corpuscular motion or Heat is increased. A certain degree of Heat produces a separation of the corpuscles of bodies which is apparent from their expa<n>sion. A greater increase of Heat or corpuscular motion so separates the corpuscles and weakens their attraction of cohesion as to convert the bodies acted upon into fluids. The greatest increase of corpuscular motion transforms bodies into elastic Fluids or Gases; the particles

9 of which by the very great corpuscular motion, which acts as a repulsive power are placed almost out of their mutual spheres of attraction & would still farther separate were it not for their absolute weight or the attraction of Gravitation.

It is a general law of Heat[5] that bodies affected with greater or less degrees of the corpuscular motion uniformly tend to communicate or receive this corpuscular motion till they all have the same temperature or the same relative quantity of corpuscular motion. The disposition in bodies to have their temperatures raised or diminished has been called their capacity for Heat. This term like many others founded upon the doctrine of caloric, <is exceptionable> It is however better to employ it than to multiply words. The capacities of bodies for corpuscular motion are emminently [sic] different. In proportion as bodies require smaller or large quantities of corpuscular motion to raise them to the same temperature they are said to have less or greater capacities. ---

This Capacity in bodies for the corpuscular motion

10 is probably governed by the form of their corpuscles and their peculiar situation with respect to each other. Consequently the Capacities of Bodies follow in some measure the order of their density. Those Bodies that are most solid, most readily receive the corp^{r}. motion from the proximity of their particles the motion is easily communicated. And they

---

are known. --- **8** The word corpuscular Motion is liable to no exception I shall therefore use it to express the cause of our sensations of Heat & as the cause of those changes in bodies which are consequent on an increase of temperature. ---

[5] Read that bodies having their particles affected with greater or less quantities of corpuscular motion.

are generally found to have the least capacity for the corp^{r}. motion. Fluids have generally a greater capacity on account of the greater distances of their corpuscles. Gases or elastic vapors the particles of which are still further separated, by a very great repulsive motion have in general the greatest capacities of all substances. When bodies in contact communicate the corpuscular motion The motion gained or lost by one body or bodies is uniformly equal to that lost or gained by the other body or bodies. When two similar & equal bodies of different temperatures be brought in contact they acquire a common temperature by communication of their corpus^{r}: motion and the common temperature will be an arithmetical mean between the two original temperatures. If two unequal & similar bodies acquire a common temperature by communication, the surplus of Heat will be found to have been divided between them in prop^{n}.

11 to their quantities of Matter. If the two bodies be of different capacities, The surplus of Heat will be divided between them in proportion to their quantities of matter & their capacities. --- That quantity of corpuscular motion to which bodies owe their peculiar states of Solidity, Fluidity and Gasity has been generally called their latent Heat. From what has been said before, it is evident that if bodies from a solid form become fluid or Gaseous, they must gain a certain quantity of corpuscular motion, either from the impression of an external force communicating motion as Friction or percussion or from the communicated motion of some body of a higher temperature. On the contrary when bodies from a solid form become[6] fluids or from fluids become Gases, It is evident they must communicate a certain quantity of corpuscular motion to some body or bodies of lower temperature – Considering these principles it will not be difficult to <account> for the cold produced by evaporation & the Heat consequent on condensation. When bodies in contact with us or in contact with the air near us become fluid or gaseous, there is generally a degree of sensible cold. This is not always as cold relative to our sensations;[7] but an absolute cold, as is

12 evident from the freezing of water by the evaporation of ether. To explain this it is necessary to observe that small portions of Ether, Alcohol &c exposed to the atmosphere take the gaseous form at its common temperature & even below 32° as is evident from Exp^{t}.

[6] The sensation of cold arises from a communication of a portion of our corpuscular motion, to some body or bodies of a lower temperature[.] It is probable that cold & & [sic] the consequent shiverings may be felt from peculiar changes of the corpuscular motion taking place in the system.

[7] are converted into ---

When these bodies evap<or>ate it is evident that they must gain corpuscular motion from the bodies in contact & the bodies in contact must consequently become colder. If some of the surrounding bodies are better conductors of Heat than others, their Heat will be subtracted quicker. For example. When a Glass tube is filled with water & continually kept wet on the outside with ether, the water is converted into ice. The ether evaporating at the common temperature of the atmosphere abstracts a portion of the corpuscular motion both of the air & water. The water not being in contact with any body that can supply it with corp^{r}: motion and being a quicker communicator of Corp^{r}. motion than air will have its corp^{r}. motion quickly [8]absorbed by the ether taking the gaseous form. And Ether taking the gaseous form even below 32° will subtract the corp^{r}: motion of the water till it loses that portion which is essential to its fluidity. It then becomes ice. ---

There are likewise other reasons for the sensible cold occasioned by evaporation which have not been before noticed

13 as I believe. --- Air is capable of holding in solution considerable quantities of Ether, Alcohol water and other fluids. Holding these fluids in solution it becomes a better conductor of Corpuscular motion & consequently subtracts it from those bodies of a higher temperature quicker than before. The cold felt by us on the evaporation of Ether, Alcohol water &c is owing to three causes. 1st. The fluid being of a lower temperature than our bodies subtracts[9] from them a portion of Corpus^{r}. Motion whence the sensation of cold 2^{dly}. The air dissolved a certain portion of the fluid & becoming a better conductor of Corp^{r}. motion absorbed that of our bodies faster than before 3^{dly} The fluid taking the gaseous form gains part of its corpuscular motion from our bodies & as well subtracts a portion from the air - Hence the third cause of cold. Those three causes act conjointly in producing a common Effect. ----------

The sensible Heat produced by Condensation may from what has been said be easily accounted for.-

Whenever a Gaz is condensed, it must be from the communication of a portion of its corpuscular motion to some body or bodies of a lower temperature, which body from the

[8] Read subtracted The reason why they are disposed to take the form of Gas whe[n] exposed & not when confined in closed vessels is from the resistance given to their elastic force by the vessel confining them

[9] Read deprives of

communication must have its temperature increased. If the particles of a body having such a quantity of corpuscular motion as to be a permanent Gas be made to appear

14 nearer to each other than when in their natural state whilst their absolute repulsive power or corpuscular motion remains the same. They will when this external force is removed consequently regain their former situations with respect to each other. This is called Elasticity. –

Bodies would as soon as heated to a certain degree take the gaseous form at one moment were it not for the circumambient atmosphere which prevents this effect 1st By its pressure, which balances the elasticity the body derives from Caloric[10] 2dly By Subtracting a portion of that Corpuscular motion which had otherwise converted the body into a Gas. The repulsive motion would indefinitely separate the particles of Bodies did not the attraction of gravitation & cohesion preserve them together **X** The absolute distances of the corpuscles of bodies & the velocities with which they move will be in the compound ratio of their corpuscular motion, their cohesive attraction & the attraction of gravitation –

[11]The quantity of corpuscular motion of bodies is increased when the particles are made to move or vibrate with greater velocity either from the impression of an external

15 force communicating motion or from the chemical or mechanical condensation of Fluids or Gases. Hence we must expect Heat in all chemical processes in which [12]light is liberated, Fluids or Gases condensed, or a rapid motion generated by composition or decomposition – We have every reason to suppose from the foregoing experiments & observations that Heat is Motion. It is evident then that those Gases which M. Lavoisier & the French Nomenclators have supposed to be simple substances combined with Caloric must be either simple substances in the Gas state ie rendered into the state of elastic fluidity by the separation of their corpuscles by the corpuscular motion or combinations of two or more simple substances, in the Gas state. Hydrogen & Nitrogen Gas we have not yet been able to decompose. They are then relative to the present state of our knowledge simple substances. Oxygen Gas as will be hereafter proved is composed of Light and Oxygen ---

[10] Read The impression of an external force upon bodies communicating motion is one cause of an increase of temperature in bodies

[11] Read *Corpuscular motion

[12] [Note indicated, but none given]

From what has been said It will be easily seen that the word Gas adopted by the French nomenclators to express the chemical combination of Bodies with Caloric is very exceptionable. The following argument will I think prove that it ought not to remain in the nomenclature of Chemistry ---

16 For 1st Bodies when rendered from solids into fluids & ~~from fluids~~ & from fluids into Gases are not essentially altered. Their corpuscles are farther separated (ie they move in a greater space than before[)]; but the body still remains as simple as before. The word then that expresses a chemical combination of caloric with bodies is improper.—

2dly All bodies with which we are acquainted have certain quantities of corpuscular motion & they have three different modes of existence, dependent on their quantities of corpuscular motion. Those modes of existence are solidity, Fluidity and Gasity. In each of these states They are equally simple. That state in which bodies are usually found at the common temperature of our planet, is the state from which they derive both their common & philosophic names. Now the French Nomenclators have called all <simple> substances (the gases excepted) by their common names, without making any alteration to express their combination with caloric.---

They have called all the metals (which are capable of existing like other bodies in three states) by the common names – on their own principles these Bodies are combined with caloric as well as the Gases. They should therefore have distinguished them by names expressing this combination & should have called Gold mercury & Sulphur – Solid Gold

17 Fluid Mercury & solid Sulphur as well as have called Azote & Hydrogen (which appear to be metals in the state of elastic vapor) Azotic Gas & Hydrogen Gas.---

3dly. Those substances which have been called Gases uniformly exist at the common temperature of our Planet in the state of elastic fluidity. Simple names without the addition of Gases would distinguish them from all other substances. With the same propriety that we make use of the term Hydrogen Gas in Chemistry we might use the terms solid Gold, fluid mercury, solid nitrate of potash – In treating of the changes made in bodies by the corpuscular motion, we may with propriety apply the terms solid fluid & Gaseous to express the different modes of existence of the same body. But simple substances should be distinguished by names characteristic of their properties – Compound substances should be distinguished by names expressive of the combination, ie of the substances forming the

compound. In conformity to these principles I shall omit any words signifying the peculiar modes of existence of bodies. And treating of substances I shall give them their simple names & by those names I mean to express the state in which they exist at the common temperature of the earth. As for example in using the words Gold Mercury & Hydrogen I mean solid Gold, fluid mercury & Gaseous Hydrogen.

18 Oxygen Gas which the French Nomenclators have assumed to be Oxygen combined with Caloric will be proved to be a substance compounded of Light and Oxygen. ---

It would be highly improper to use either the terms Oxygen Gas or Oxygen, The one would signify that it was a simple substance combined with caloric (acc^{g}. to the French Nomenclators) & The other that it was a simple substance – The term PHOSOXYD[13] will I think be unexceptionable. It will express a combination of the simple substance Light with the simple substance Oxygen. It will not materially alter the nomenclature of the French Philosophers & as will be seen by & by it can be easily modified to express in conjunction with other words, The combination of Oxygen & Light.

Of Light and its Combinations.

Light is a body in the highest state of elastic fluidity.-

Its particles are so amasingly minute, that tho' moving with the greatest velocity they communicate no sensible impulse to bodies and pass almost unaltered thro' the pores of diaphanous bodies. So great is the elasticity of Light, that when it strikes against bodies that have no attraction for it & that it cannot penetrate or combine with it is reflected

19 unaltered & the angle of reflection is always nearly = to the angle of incidence.-

From the emminent [sic] elastic fluidity of Light we must account for its velocity.- The influence of the attraction of Gravitation on Light is very small as is evident from its not apparently gravitating towards the sun or the earth, The influence of the attraction of cohesion is likewise very small as is evident from the tendency of the rays of Light to separate; but the repulsive motion acting on the corpuscles of Light is very great as is evident from their uniformly separating. But as we have said before the distances of the

[13] From Φως and Οζνς

corpuscles of bodies from each other and the velocities with which they move are in the compound ratio are in a ratio compounded of their attraction and repulsion. When the corpuscular or repulsive motion predominates over the cohesive & gravitative attraction the particles of Matter will be indefinitely separate as those of light. Light is the source of the most numerous & pleasurable of our sensations and ideas. This tribe of sensations is thus received. Particles of Light moving with the greatest velocity, strike upon the retina which appears to be decomposed of nervous medulla & irritable fibre - The stimulus of Light either produces a contraction of the irritable fibre, which contraction is accompanied with that affection

20 of the nerve corresponding to a sensation, or the stimulus of light in the nervous fibre produces a sensation. -

The former of those opinions is rendered very probable by the Exp^{ts} on [sic] D^{r} R Darwin on ocular Spectra, vide Darwins Zoonomia V^{o} 1st. ---

The Sensations then that we receive from light must be different in proportion as the magnitudes or velocities of the particles of Light are different. The difference of colors then & the decomposition of rays by the prism will not affect the supposition that Light is a simple substance. ---

Light is perceived under three different modifications which are generally though improperly distinguished by the names of Red or white Heat, Flame & Light[.] Philosophy demands a more unequivocal nomenclature and since Light & Heat are totally different they should be distinguished from each other by proper & expressive Names. ---

The red or white Heat is always apparent when Oxygen Gas is decomposed by a solid body which at the temperature of combustion has no tendency to take the gaseous form, as when Oxygen Gas is decomposed by pure Carbon. It is likewise apparent when solid bodies which have no affinity of Oxygen are placed in contact with a strong light as when Glass is made red hot. The red that appears to be owing to the strong

21 cohesive attraction between Light and the solid body & it may with propriety be called solid Light[14] being Light not yet in the state of elastic Fluidity. For a certain quantity of

[14] This Theory of the luminous appearance of bodies may be compared with Macquers or Newtons. Fourcroy says Tom 1, p 96. The ignition of incombustible bodies has been very ingeniously explained by Macquer. In his opinion it depends on the strength of vibrations communicated to the particles of these bodies by the impulse

corpuscular motion is essential to the Gaseous form of Light when Light is deprived of that quantity of corpuscular motion it must become fluid or solid. In the decomposition of Oxygen Gas as will appear from what has been said on condensation a certain quantity of corpuscular motion is generated. This motion is partly communicated to the liberated light & partly to the oxygen attractor. A portion of the liberated light not yet supplied with its necessary quantity of corpuscular motion surrounds the Oxygen attractor & gradually subtracts its corpuscular motion to supply its increasing capacity. That this Theory is <true is> evident from the gradual diminution of the brightness of a body heated red. Flame is apparent when Oxygen Gas is decomposed by an elastic fluid or Gas as in the decomposition of PHOSOXYD or OXYGEN GAS by Hydrogen. It appears to be light in the process of decomposition attracted by the Gas. It may be called

22 Fluid Light. Light when perfectly freed from the attraction of other bodies & supplied with its necessary quantity of corpuscular motion is in an emminent [sic] state of elastic fluidity & then may be properly called Light. –

Light then like almost all other bodies with which we are acquainted is capable of existing in these states. The solid fluid & gaseous forms & each of these forms depends upon its quantity of corpuscular motion. In the temperature of our earth it is seldom seen in the solid or liquid forms, except during its attraction by other bodies. In the sun & fixed stars it exists probably under these forms. Portions of solar fluid or fluid light regularly & continually taking the gaseous form provides the planetary regions with light & as will be by & by proved spreads over our earth Organization, perception & happiness.

- Light acting upon certain bodies produces Heat & the Atmosphere Heat is generally proportionable to the solar Light. The cause of the solar Heat is a subject of great

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of heat. Those vibrations disposing the particles in such a manner, that their facets acting like so many little mirrors **22** reflect upon our eyes the rays of Light, which exist in the air by night as well as by day. For we are involved in darkness during the night for no other reason but because these are not then so directed as to fall upon our organs of sight /// A most curious explanation. How much men philosophise is the common opinion of Mankind who ignorant & unphilosophic suppose that the presence of the Sun is the cause of Light & his absence of darkness ///-- Newtons opinion is more ingenious. He supposes that when the corpuscular motion of bodies is raised to a certain degree The agitation throws off some subtle particles or effluvia which excite the idea of light.-- that when the particles of bodies are violently agitated - They not only throw off lucid particles but also shine themselves & then when the bodies are solid the red **23** Heat is produced when they are in a fuming state the Flame. --- The first Exp^{t} confutes the last opinion that light is the effect of Heat & it will appear in the course of these exp^{ts} & observations That fixed & fluid light are never present but when Oxygen Gas or phosoxyd is decomposed, or light condensed by solid or fluid bodies. ---

23 importance to Physics & worthy of investigation.---

Heat has been proved a peculiar motion of the corpuscles of Bodies. Light is a body emminently [sic] gaseous ie the particles of which move with the greatest velocity. When then a body has its corpuscular motion increased by the action of Light, a portion of the corpuscular motion of Light must be lost, a portion equal to that gained by the body acted upon. This is evident from what has been said on the communication of corpuscular motion, in the doctrine of Heat.

Different bodies are differently heated by the action of Light; and this difference has been known to depend in some measure on color. To discover the correspondence between the increase of corpuscular motion in bodies and their color I made the following exp^{t}.

EXPERIMENT 5TH. Six similar pieces of pasteboard of equal weight size and density were thus colored. One white one yellow, one red one green one blue & one black. ---

A portion of a mixture of oil & wax which became fluid at above 70° was placed on the center of each on the inferior side. –

They were then attached to a board painted white & so placed <with reg^{d}> to the sun that their upper surfaces were equally exposed to the light. their interior surfaces to which the cerate was attached

24 were equally deprived of Light and Heat ie They we so exposed that there could be no mistake with regard to the corpuscular motion generated in them by the action of light. --

The changes of temperature in them from the action of light took place in the following order. The wax on the black pasteboard began to melt perceptibly before the rest. The blue next in order, then the green the red next, the yellow at nearly the same time as the red. The white was scarcely at all affected when the black was in a compleat [sic] state of fusion. -

This Exp^{t}: proves that the corpuscular motions generated in bodies by light are correspondent to the sensation we receive from reflected light. Now when bodies have their corpuscular motion increased by light, it is evident that a portion of the c^{r}. motion of light equal to that gained by the body must be lost and the reflected light must consequently move with less velocity than before.[15] But our sensations of colors arise from the impulse of

[15] ie vibrate

the particles of Light on the retina. This impulse most probably stimulates the muscular fibre of the retina; which contracting affects the nerve with a sensation. In proportion as the impulse, that is the stimulus, is greater or less the contraction of the irritable fibre or the affection of the nerve must be likewise greater or less. Consequently as the velocities of the rays of light are different so must the sensations we receive from them be different. ---

25 It will not appear improbable from what has been said on the corpuscular motion, that the particles of light may be affected with a vibratory motion and these vibrations whether long or short may be preformed [sic] in equal times & every particle of light may move thro' space in equal times, but in proportion as the vibratory motions of the particles of light are different the affectations of the optic nerve will be different. Of course when a particle of light communicates a portion of its corpuscular or vibratory motion to bodies it must affect the organs of sense with a different sensation & all the differences of color correspondent to the increase of temperature in bodies may be accounted for by the differences of the vibrations of the particles of light, without supposing that their absolute ~~velocities~~ <times of moving thro' space> are different, For example the white rays which appear to communicate no corpuscular motion may vibrate in the greatest space. The rays reflected from black bodies may move with the shortest vibrations. ---

And all the intermediate colors may depend on the different lengths & consequently velocities of the vibrations[.][16]

26 To demonstrate that the difference of temperature corresponding to the difference of color does not depend on an alteration of the capacities of the bodies for the corpuscular motion <by the coloring matter>, I made the following Exp^{t}:

EXPERIMENT. 6TH The pieces of pasteboard made use of in my last experiment were fixed as before to the board printed white & equally exposed in a dark room to ~~wat~~ the heat of water of about 200°. The cerate on the different pieces began to melt at the same time & at the same time were in a state of fusion. -----

Light then raises the temperature of bodies by communicating to them its corpuscular motion. The capacities of bodies for receiving the corpuscular motion <of light>

[16] All the phænomena of the decomposition of the rays by the prism their refraction, their similarity &c &c may on this supposition be easily accounted for. --

are not the same as those by which they receive the communicated corpuscular motion of other bodies; but depends upon a peculiar configuration of their particles now unknown to us but which we believe to be the cause of their colors. -

The increase of the corpuscular motion of a body by the action of the solar light depends upon the capacity of the body for the corpuscular motion of light and its absolute capacity for corpuscular motion, as for example a piece of lead painted white is much more difficultly heated by the action of light than a piece of lead colored black but both have an equal absolute capacity for Heat.

It is not at all improbable that the rays of light ~~communicated to the particles of~~ <lose in passing thro> the atmosphere a very small portion of

27 their corpuscular motion, which is the cause of the atmospheric heat, Water, Glass & other transparent bodies are capable of being heated by the solar rays & the rays of light in passing thro' them receive a different tinge for a body perfectly white appears colored in deep water. Is not the blue colour of the air a proof that the corpuscular vibration of light is partially diminished in passing thro' it? - It is probable that to an eye placed out of our atmosphere light would appear of a color now unknown to us. It is certain that a great portion of water is held in solution by atmospheric air. May not the atmospheric Heat be in a great measure owing to this water. Which during the day is taken up or converted into vapor by the action of the sun upon it, kept in solution by air to give the necessary heat to the atmosphere & in night thrown down in dew, still to communicate heat to the air by its condemnation. ---- Is not the refraction of light occasioned <in a great measure> by the aqueous vapor in the atmosphere, for the rays of light are not refracted above 45 miles high & we are certain from the phenomena of fiery meteors, that the atmosphere extends at least as high again -----[17]

28 Of the Combinations of Light.

Oxygen Gas[18] is Light combined with Oxygen.

[17] [No indication of location] tinged with yellow or green. – Dr Hall[e]y in the diving bell exposing his hand to the solar rays it became tinged red.

[18] Phosoxyd [here and in the following notes on this page, Davy refers using the same symbol to the note five more times]

A number of bodies when heated to a certain degree and placed in contact with Oxygen Gas[19] become surrounded with fixed or fluid light. The Oxygen Gas[20] is rapidly diminished with a great increase of temperature. The body after combustion is found weightier than before: ~~and~~ this increase of weight is nearly equal to the Oxygen Gas[21] consumed in the process, and the new compound has properties essentially different from either Oxygen Gas[22] or the base. That this account of combustion is true will appear from the following Exp^{ts}. ---

Experiment 7th. If Carbon[23] having its temperature raised to a certain degree is placed in contact with Oxygen Gas[24] it becomes surrounded with fixed or fluid light, the Carbon and Oxygen Gas are both diminished with a great increase of corpuscular motion in the surrounding bodies. If they are both pure & to each other in the proportion of 28 to 72 they entirely disappear & carbonic acid gas is formed nearly equal to the carbon & Oxygen Gas. It is not quite equal as I have proved by exp^{t}. I do not know exactly this defficiency [sic], but **29** it appears to me to be 3 or 4 100 parts. It is owing to the light liberated in the process. ---

Experiment. 8th. When Sulphur is heated in contact with Oxygen Gas or Phosoxyd it becomes surrounded with fluid light. The Oxygen Gas & Sulphur are rapidly diminished with great increase of temperature and Sulphuric acid Gas is formed. If they [sic] Oxygen Gas be very pure & there be sufficient Sulphur They will both disappear & Sulfuric [sic] acid Gas nearly equal to the Oxygen Gas & Sulphur will be formed. The deficiency of weight is owing to the liberated light. ----

Exp^{t}: 9th. When the temperature of Phosphorous in contact with Oxygen Gas is raised to 160° it becomes surrounded with fluid Light. The Oxygen Gas & phosphorous are rapidly diminished & Phosphoric acid is formed. This acid as I have proved by direct Exp^{t}. is not equal in weight to the Phosphorous & Oxygen Gas employed in the process this deficiency appears to be about 1/60th part. It arises from the liberation of Light. —

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[19] Phosoxyd

[20] Phosoxyd

[21] Phosoxyd

[22] Phosoxyd

[23] pure charcoal freed from Hydrogen ---

[24] Phosoxyd

Exp^{t}: 10th. When the temperature of Hydrogen Gas in contact with phosoxyd or Oxygen Gas is raised to 340° The Gases combine fluid light is liberated & water nearly equal in weight to the gases employed is formed[25]. ----

30 A Number of bodies will be hereafter proved combine with both light and Oxygen or Oxygen Gas and many of the metals are of this kind; these bodies then when heated & placed in contact with Oxygen Gas combine with it; but no Light is liberated. But there are other metals which attract only Oxygen & others which attract Oxygen & portions of Light. These when placed in contact with oxygen Gas & heated become surrounded with ~~light~~ greater or less quantities of light as the following exp^{ts} will prove. ---

Exp^{t}. 11th. When Zinc is heated in contact with Oxygen Gas it becomes surrounded with fluid light. The Zinc & Oxygen Gas are diminished and Oxyd of Zinc is formed. -

Exp^{t}: 12 The Oxydation of Iron by Collision with flint affords a striking proof of this doctrine as well as of the Theory of Corpuscular motion. I have made some new Exp^{ts} upon it. As in Exp^{t}: 1st. Iron by collision with Flint in Hydrogen Gas, in vacuo & in Carbonic acid Gas produces no light. - Small globules are separated from the Steel which when examined by the microscope appears to have been fused. When Steel is violently struck by Flint in Oxygen Gas or atmospheric air bright Sparks of light are produced & small particles of Steel are found oxydated[.][26]

31 From these Experiments then it is evident, that whenever certain Oxygen attractors combine with Oxygen to form Oxyds & acids Light is liberated -- Since Light is liberated, as it is matter, the cause and not the effect of Heat, it is evident, that it must be liberated from one of the two combining bodies by the superior affinity of the other for the luminated base. — Stahl and the Phlogistian Philosophers in general supposed, that the flame & Heat the effects of combustion were occasioned by the liberation of the phlogiston or principle of

[25] The composition of water, that most important chemical truth was discovered by Cavendish & Lavoisier at nearly the same <time>. The latter has given the most convincing synthetical & analytical proofs, Traite elementaire Tom. premier

[26] With a similar apparatus two Flints were made to strike together in vacuo, but no light was produced in carbonic acid Gas; but no light **31** was produced. Small particles of Flint were separated unaltered. When the Collison was made in Oxygen Gas or atmospheric air Light was produced, small pieces were separated from the Flint which examined by the microscope appeared whiter than before. Now it is evident since Oxygen Gas is decomposed, that the Oxygen must either combine with the Flint or some metallic substance in the Flint whilst the light is liberated. This Exp^{t} may lead to some discovery of the nature of Siliceous earth. I am about to make exp^{ts} on it with a better apparatus. ---

inflammability, which they believed to be contained in all combustible bodies.[27] Lavoisier & the antiphlogistians supposed combustion to be the decomposition of Oxygen Gas which they assumed to be Oxygen combined with Caloric. The light produced in combustion was by some of the calorists supposed to be an effect of Heat

32 and by others a component part of Oxygen Gas. ---

It has been proved that the caloric or igneous fluid of the antiphlogistians &c does not exist. The Heat produced in combustion arises from the liberated light, the rapid corpuscular motion generated by combustion & the condensation of a Gas or Gases. The Light as I have before said must be fixed from one of the two combining bodies by the superior affinity of the other for that body. - Let it be supposed to be <freed> from the combustible base ie from the Oxygen attractor. -

Then are combustible bases compounds of simple substances & Light & Oxygen Gas a simple substance. And Combustion on this supposition is the decomposition of a luminated base by the affinity of Oxygen Gas (a simple substance) for the base. Those compounds then of Bases & Light when they ~~combine with~~ are decomposed to combine with Oxygen Gas must give out their Light & become compounds of Oxygen Gas & Bases or oxyds or acids[.]

For example Iron is supposed on this Hyp^{s} to be a peculiar unknown simple substance combined with light when this combustion of a simple substance & light is placed in contact with Oxygen Gas a simple substance & heated its affinity for Oxygen Gas becomes superior to its affinity for light. It gives out its light combines with the oxygen Gas & becomes an OXYD.—

33 Since Oxygen Gas is a simple substance, it necessarily follows that when a luminated base becomes oxydated by attracting Oxygen Gas from any of its combinations it must give out light. But oxydable bases may be oxydated by attracting oxygen from its combinations without giving out light & thus oxydated they are in every respect similar to those Oxyds formed by combustion as when iron is oxydated by the decomposition of water &c without the liberation of Light. It is then absurd to suppose that the light liberated in combustion arises from the oxydable or acidifiable base. Since it does not arise from the base, it must

[27] Macquer (as I believe) supposed light to be the Phlogiston & Kirwan Hydrogen

arise from the decomposition of Oxygen Gas or PHOSOXYD which is consequently a combination of OXYGEN and LIGHT. —

[28]Combustion then is a simple elective attraction, or the decomposition of Oxygen Gas or Phosoxyd by the affinity of the oxydable base for the oxygen. The light of the Phosoxyd is liberated in the process & the increase of temperature arises from the liberated light & the corpuscular motion generated by combination & Condensation. —

34 To explain the phænomena of Combustion by their Theory, the Phlogistians were obliged to consider all combustible bodies as combinations of different unknown simple substances with the undemonstrated Phlogiston & Oxygen Gas or vital air a simple substance.—

The Theory unphilosophical as well as false tended to confuse science by refferring [sic] to ~~so~~ many unknown principles, to account for phænomena which evidently depend upon known ones. -

The phænomena of combustion are easily explained on the theory of corpuscular motion & only one unknown principle is admitted. Oxygen which we have never been able to obtain in its simple state on account of its strong attraction for Light but whose existence we can demonstrate in a number of bodies. ---

The theory of the great Lavoisier has only these defects. The assumption of the imaginary fluid Caloric & the total neglect of Light. According to the Calorists combustion ought always to take place whenever the Gases were condensed. But none of the Gases (except those of which Oxygen Gas is a component part) however rapid their combinations or decompositions produce the smallest combustion or liberation of light. When Hydrogen, Azotic & Carbonic acid Gases unite to form carbonate of Ammoniac no light is liberated & the increase of temperature is no more than may well be accounted for by the motion of comb^{n}.

35 It is then demonstrated analytically that PHOSOXYD or OXYGEN GAS is LIGHT combined with OXYGEN; but it may be likewise documented synthetically.

Synthetical Proofs

[28] It might be more accurately expressed. Combustion then is the decomposition of Phosoxyd or Oxygen Gas by the simple elective attraction of the oxidable base for oxygen &c ---

OXYGEN GAS is LIGHT combined with OXYGEN

[29] Of those substances that have been heretofore distinguished by the common name of Oxygen attractors There are some as has been before said that decompose Oxygen Gas or Phosoxyd & combine with the Oxygen whilst the Light is liberated. These Oxyds require a great quantity of light to decompose them. In this decomposition the light combines with the Oxygen to form Phosoxyd & the substance again becomes combustible as the following Exp^{ts}: will prove.

Exp^{t}: 13th. If pure Oxyd of iron be heated as much as is possible without the ~~liberation~~ <presence> of Light, it remains unaltered but when placed in the vacuum of a receiver in contact with the strong concentrated light of a large burning Glass, PHOSOXYD or OXYGEN GAS is formed & the metal is revivified

36 Exp^{t}: 14 When pure oxyd of Lead is heated as much as possible excluded from Light it remains unaltered but when exposed to the fluid light of a candle it gives out Oxygen Gas and become revivified.

From these exp^{ts} it appears that whenever Oxygen Gas or Phosoxyd is formed from pure Oxyds Light must be present & Oxygen Gas is never formed from pure oxyd but when Light is present. An increase of corpuscular motion is likewise sometimes necessary to divide the aggregated particles, so that the attraction may take place. Very few of the pure Oxyds or acids are decomposed by light The greater part of them are decomposed by substances which have a stronger affinity for Oxygen, as carbon, Hydrogen &c

Those substances that partially decompose or almost whol[l]y combine with Phosoxyd or Oxygen Gas are more easily decomposed by Light. The~~ir~~ attraction between the base & oxygen is weakened by the attraction between Light & oxygen & the addition of a small quantity of light effects the decomposition. Oxygen Gas or Phosoxyd is formed & the substances are restored, as the following

37 Exp^{ts} will prove. ---

Exp^{t}: 15th. Oxygenated muriatic Acid is compound of muriatic acid, Oxygen and light as will be by & by proved. This light is not sufficient to attract the Oxygen from the base to form

[29] Add here. Exp^{ts} on the decompositions of combinations of Oxygen by the simple elective attraction of light for oxygen.

Oxygen Gas, but its attraction for the Oxygen renders the acid easy of decomposition. If this acid be heated in a close vessel & light excluded no Oxygen Gas is formed; but if it be exposed to the action of the solar light Oxygen Gas is produced. The acid loses its Oxygen & Light & become muriatic acid. Now since Light acting mechanically ie producing corpuscular motion cannot by the first part of this exp^{t}: decompose Oxygenated muriatic acid, it must evidently act chemically ie attract Oxygen & light from the acid and this combination of Oxygen & light is Oxygen Gas.---

Exp^{t}: 16 If Nitric Acid which is compounded of Nitrogen, Oxygen & light, as will be hereafter proved be exposed to the Solar light, Oxygen Gas is formed & the Acid is reduced to the state of nitrous Acid ie is deprived of a portion of its Oxygen & Light. ---

38 Exp^{t}: 17th. The Oxyd of Tungsten consists of a peculiar metallic base, Oxygen & probably a small portion of light. It is of a yellow color. If this oxyd be exposed to the solar light Oxygen Gas is produced & the Acid becomes of a bluish color.

Exp^{t}: 18th The green prussiate of Iron exposed to Light gives out Oxygen Gas & becomes blue.

Exp^{t}: 19 If the Oxyds of Gold or Silver be exposed to the solar light, Oxygen Gas is produced & the metals are revivified.----

From these Exp^{ts} it appears that the Acids & Oxyds ~~are~~ never give out Oxygen Gas but when light is present & that the quantity of light necessary to effect the production of Oxygen Gas is proportional to the quantity contained in the combination. Those Substances that contain portions of light combined with their Oxygen readily give out Oxygen Gas when placed in contact with Light. Those on the contrary that are pure oxyds, as Oxyds of iron, nickel &[c] require large portions of concentrated light to disengage from their Oxygen Gas –

39 Certain combinations of Oxygen cannot be decomposed by the simple elective attraction of Light for Oxygen. These require for their decomposition the united force of two attractions That of Light for Oxygen & of some substance for the Oxydable base as the following Exp^{ts} will prove.---

EXPERIMENTS on the decomposition of Combinations of Oxygen with bases by the force of two attractions that of light for Oxygen & of some substance for the Oxydable base.-----

Water as is proved by Exp^{t}: 10th. Is composed of Oxygen & Hydrogen. When the Oxygen of Oxygen Gas combines with Hydrogen Light is liberated. Water is decomposed by

two attractions that of Light for Oxygen & of a certain Hydrogen attractor for its Hydrogen. The marine Cryptogamia vegetables & a great number of other substances attract Hydrogen. The attraction of the Marine Cryptogamia for Hydrogen is very strong as the following Exp^{ts} will prove.---

Exp^{TS} on the Marine Cryptogamia.

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40 Exp^{t}: 20. The marine Cryptogamia derive their nutriment from water or from substances held in solution by water. By Analysis they afford a considerable portion of Hydrogen Gas, Carbonic acid Gas, Water a small portion of muriatic acid Gas, Carbon & Soda. The sea water is composed of Oxygen & Hydrogen & holds in solution Carbonic acid, muriate of Soda & small quantities of other salts.-

Seaweeds being composed of Hydrogen, Carbon, water & muriate of Soda must then decompose both water & Carbonic acid of which the Hydrogen & Carbon combine with them & the Oxygen is liberated by means which will be hereafter related. It is then proved analytically that the Marine Cryptogamia attract Hydrogen but it may be likewise proved Synthetically.—

Exp^{t}: 21st. One cubic inch of Conferva fæniculacea previously dried was put into a Phial containing 13 cubic inches of Hydrogen Gas. It remained in a heat of 58° for six hours & at the end of that time was examined. The Hydrogen Gas was diminished 8/10^{s} of a cubic inch, I could get no ballance sufficiently accurate to determine

41 the weight gained by the Conferva. As the marine Cryptogamia cannot be obtained perfectly dry it was necessary to prove that the Hydrogen Gas diminished was not absorbed by the water. For this purpose two Phials containing each 12 Cubic inches ~~were~~ ½ were filled with Hydrogen Gas. One cubic inch of Conferva fæniculacea was inserted into the one & two cubic inches of spun horse hair previously wetted into the other. The quantity of Gas in each of them was then accurately determined. The Phials were inverted in the same vessel of water & at the end of 12 hours examined.—

The diminution by the Conferva was near a cubic inch & quarter, by the horse hair & water not more that 3/10^{s} of an inch---

Exp^{s} on the decomposition of Water.

The last Exp^{t} proves that the marine Cryptogamia attract Hydrogen gas; but their affinity for it is weaker that the affinity of Oxygen for Hydrogen.[30] Water therefore is never decomposed by the simple elective attraction of bodies for its Hydrogen. ---

42 That does not effect the decomposition of water as the following Exp^{t}. will prove Exp^{t}: 22^{d}. One hundred & four cubic inches of sea water previously boiled to expel from it atmospheric air were heated with three cubic inches of Conferva fusca in a vessel from which Light was excluded. The Heat was gradually raised to 200°; but not more than a few globules of Gas were formed; which by trial with nitrous Oxyd Gas proved to be of the same quality as atmospheric air. This exp^{t}. alone seems to prove that Oxygen Gas is not Oxygen rendered into the Gas state by means of heat.----

Water exposed to the solar Light in contact with the marine Cryptogamia or any Hydrogen attractor is decomposed by the force of two attractions, that of the Hydrogen attractor for Hydrogen & of Light for oxygen as the following Exp^{ts} will prove.—

Exp^{t}. 23^{d}. Into a green Glass globe containing 214 cubic inches filled with sea water previously boiled, one cubic inch of Conferva littoralis was inserted. The globe was inverted in a jar of water of a similar kind & exposed in a bright sunshine for four hours. In this time five cubic inches of Gas were formed, which by trial with nitrous Oxyd Gas proved to be seven parts Oxygen &

$$\frac{7}{3} \quad \begin{matrix} 71 \\ 29 \end{matrix}$$

43 three Azotic Gas. The next day the globe was exposed to the light for three hours. Two cubic inches & five tenths were produced. It proved to be six parts Oxygen & 2 parts Azote. The next day the Globe was exposed for five hours; but the sky was often clouded & there fell some showers. Two cubic inches were form'd 8 parts Oxygen & 2 Azote. On the fifth day of the exp^{t} the sun shone very bright for four hours. Three cubic inches were formed 18½ Oxygen and 1½ Azote. After this all the Gas formed contained from 16 to 18, 20^{s} of Oxygen Gas. The other Gases combined with the Oxygen appeared to be Nitrogen Gas & carbonic acid Gas at the latter part of the exp^{t} there was some indication of the presence of Hydrogen

[30] The marine Cryptogamia or vegetables, placed in contact with water & dep^{d} of light produced no Gas & effect no alteration in the water as long as they retain life.---

Gas. The whole quantity of Gas produced from 214 cubic inches of water in 36 hours of sunshine was 46 cubic inches of the mean quality of 17 parts Oxygen Gas or Phosoxyd & 3 Azotic Gas.[31] ----

75 . 25 : : 6 2 60 20 70 30:
2 3
150

44 I have made a number of exp^{ts} on the decomposition of water the particulars of which it is unnecessary to mention here. The observations that I made during the course of these exp^{ts} were – 1st That an increased or diminished temperature produced no difference in the production of Gas for no difference was perceived in the production at 51° & 68° - 2^{dly} That a very strong artificial light acts similarly to the solar light - 3^{dly}. That the quantity of Gas produced is nearly in proportion to the quantity of Gas absorbed[32] & the surface of the Hydrogen Attractor

For the capillary dark colored & opaque Confervæ generated more & better Gas than the white & pellucid Confervæ. The Confervæ generated more Gas than the Fuci & the Fuci more than the Hepaticæ.-

45 I must here observe that this discovery of the decomposition of water by Light & the marine Cryptogamia will account for many phænomena before inexplicable.-

1st The Oxygen Gas supplied from the waters of the Ocean by the marine Cryptogamia will be a considerable source as a supply of that wasted by combustion & respiration – 2^{dly}. It will account for the superior purity of the sea air & of the air near the sea coasts 3^{dly}. For a phænomena observed by D^{r} Ingen=hous the superior purity of the air near the sea coasts to that on the ocean.-

[31] I must here observe that these exp^{ts} on the decomposition of water afford strong proofs of its composition, a fact which is still contested by D^{r} Priestl[e]y & some other Chemists.- Water holds in solution a considerable portion of Atmospheric air which even boiling will not entirely free it of. The Azote produced in these exp^{ts} must arise from the Atmospheric air & -

[32] I must here observe that those facts afford additional proofs of the truth of the Theory of Light. In that theory it was stated that dark colors were occasioned by a diminution of the velocity of the vibrations of the particles of Light, by the communication of portions of their motions to reflecting bodies. The particles of light must therefore remain longer in contact with those bodies & must thus more effectually act upon the oxygen of the water whilst the Hydrogen is attracted by the Cryptogamia. We as yet know but very little of the corpuscular action. Chemical not mathematical principles are the only ones by which we can hope to discover it.

These Experiments prove synthetically, that Oxygen Gas or phosoxyd is light combined with Oxygen –

It has then been proved analytically & synthetically that Oxygen Gas is Light combined with Oxygen –

Since Light is matter it must evidently have some absolute weight ie be in some measure affected by the power of Gravitation. The decomposition of a few cubic inches of Oxygen Gas is sufficient to fill a space of many miles with perceptible gaseous Light & consequently there must be a considerable portion of Light in Oxygen Gas or Phosoxyd.-

~~There are two methods by which~~ We may <thus> determine the quantity of light liberated in combustion with great accuracy

By first determining the weight of a quantity of Oxygen Gas or Phosoxyd sufficient to acidify by its decomposition any substance. Then to determine the weight of the oxydable or acidifiable base. The difference between the

46 [33]weight of the oxyd or acid & The oxydable or acidifiable base & the Oxygen Gas is the weight of the light liberated in combustion. We may also ascertain the quantity of Light necessary to convert the oxygen or any Oxyd or acid into Phosoxyd or Oxygen Gaz thus.-

By determining the weight of a pure Oxyd or Acid before its decomposition by Light, The weight of the oxygen Gas generated in the process & the weight of the oxydable base. The difference between the weight of the Oxyd, the Oxygen Gas & the base is the weight of the light.-

As we cannot absolutely demonstrate that Phosoxyd gives out the whole of its Light when it oxydates bodies by combustion, The weight of the Light discovered by those two methods will not be the certain absolute weight of the whole of the Light in Phosoxyd (ie in the quantity combining by combustion[)]; but only the weight of the light liberated in combustion & that absorbed in lumination.

[33] [Davy did not indicate where this note should go]: M [blank in MS] Oxygen combined with still greater portion of light here

[34]Though it is reasonable to supposed that in some cases of combustion, probably in the greater part of them, Oxygen Gas is whol[l]y decomposed, the Light liberated & the Oxygen

47 attracted by the base; yet there are others as will be by & by proved in which there is only a partial decomposition of Phosoxyd[.] In these only a portion of y^{e} Light of Phosoxyd is liberated; whilst the other part united to the Oxygen combines with the attracting base. And Oxygen & Light often combine with bodies without decomposition. These bodies of which we are now about to treat will be combinations of Light Oxygen & bases.-

COMBINATIONS OF LIGHT, OXYGEN AND BASES.-

---- The Nitrous Oxyds & Acids are combinations of Oxygen Light and Azote as may be proved analytically & synthetically

Exp^{t}: 24 When Oxygen Gas or phosoxyd & Azote are made to combine by the action of the electric spark, it appears that no light is given out in the process. In proportion as the quantity of Oxygen is greater the substance formed by the combination has more acid properties. Two parts of Oxygen Gas with one of Azote forms Nitrous Oxyd – Three parts of oxygen Gas or Phosoxyd with one of Azote forms Nitrous Acid & four parts Nitric Acid.----

Exp^{t}: 25 When three parts of nitrous Oxyd Gas is mingled with two parts of Oxygen Gas, The gases disappear without the liberation of Light & Nitric acid is formed equal in weight to the gases employed. These synthetic exp^{ts} demonstrate that the Nitrous Oxyds & Acids are combinations of Light Oxygen & Azote in different proportions. The Analytical proof is equally clear & will account for a phenomenon that the other Theories were inadequate to explain ----

Exp^{t}. 26th. Nitrate of Potash mingled with Carbon was fired by a burning Glass in the exhausted receiver. The conflagration took

48 place [and] a quantity of Light was liberated. The gaseous products were examined & found to be nitrogen Gas & Carbonic acid Gas. The fixed substance remaining after combustion was Carbonate of potash mingled with a little charcoal. It is evident from this

[34] I have heretofore possessed no ballance sufficiently accurate to determine the weight of Light in a fixed state – By discovering the quantity of Light liberated in combustion & by comparing the weight with the magnitude & duration of the flame we may be enabled to ascertain the specific gravity of light. These exp^{ts}. I intend to make as soon as I am possessed of a ballance & the necessary apparatus sufficiently accurate ----

experiment, that Nitric acid is composed of Azote, Oxygen & Light. Nitrate of Potash is compounded of Light, Oxygen, Azote & Potash in combination & equilibrium from this complex attraction each individual attraction is weak[.] When heated Carbon is placed in contact with Nitrate of Potash it attracts the Oxygen from it combines with it & forms Carbonic acid Gas. The Azote & Light having no affinity for each other or for potash are liberated. The Heat produced in the process arises from the rapid corpuscular motion of the combining & liberated bodies. The detonation is owing to the undulatory motion generated in the circumambient atmosphere, by the rapid dislo<d>gement of a body of air equal in Bulk to the Azotic Gas, Carbonic acid Gas & aqueous Gas formed in the process[35]. The Theory of the detonation of all the nitrate & nitrites is similar. They are all compounds of Light Oxygen Azote & Bases.[36] ----

49 Light also enters into the composition of precipitates of metals from Nitric acid by Ammoniac, One of the most astonishing of these combinations is ammoniated nitrate of silver or fulminating silver – Silver must be dis[s]olved in nitric acid & precipitated by Lime water. This precipitate must be exposed to light for some hours & during this process which is necessary to the success of the experiment it most probably combines with a great portion of Light.- Stirred in a solution of ammoniac is assumes the form of a black powder. This powder (the solution of ammoniac being evaporated in the fulminating Silver[)] – A compound of Light, Oxygen, Azote Hydrogen & Silver. From the very complex attraction the substances are weakly combined. The slightest change of temperature disposes the Oxygen & Light to combine & form Oxygen Gas. The Azote & Hydrogen having no affinity for Silver take the Gas form & a quantity of the light absorbed during its exposure to that substance is

[35] Count Rumford supposes (in a paper published in the last volume of the philosophical transactions) that the explosive force of Gunpowder is owing to the aqueous Gas generated in the process which must chiefly arise from the water of chystallisation of the nitrate of potash. It will be sufficient to confute this opinion to observe that Gunpowder made with nitrate of Soda is not near so strong as that made with nitrate of Potash altho' it contains three times as much water of chystallisation. That the formation of Gases is the great cause of this explosion is evident from the phænomenon of the air gun.---

[36] Since such is the composition of the nitrous oxyds & acids it is evident that the names given to them by the French nomenclators are improper. If Azote be admitted as the name of the base. The combination of Azote should be distinguished by names expressive of the substances forming the compound – As the nitrous Oxyds & Acids are compounds of **49** Light, Oxygen & Azote. They should be distinguished by the following names Gaseous Oxyd of Azote, the Dephlogisicated nitrous Gas of Priestl[e]y should be called ~~a~~ Azotous Phosoxyd. The nitrous oxyd Gas – the nitrous Gas of Lavoisier should be called Azotic Phosoxyd. The nitrous acid should be called Azotous Phosacid – The Nitric acid Azotic Phosacid. The terminations ous & ic & the terms Oxyd & Acid would easily point out the different proportions of Oxygen Light & Azote. But I shall treat more fully of this in my Essay on the combinations of Azote.----

liberated. The astonishing detonation produced by the decomposition of this substance may be accounted for by the dislodgment of a very large body of air equal in bulk to the elastic fluids generated in the process. The products of this detonation have never been examined.

I have ventured to differ from M Berthollet the ingenious discoverer of this substance in the explanation of the detonation. his Theory is certainly not adequate to account for the very great explosion.--

50 The detonation of Fulminating Gold may be well explained by M. Berthollets Theory if Light be substituted for Heat. ---

Oxygenated muriatic Acid is a compound of muriatic Acid Light & Oxygen as is proved by its decomposition. ---

Exp^{t}: 27th. Oxygenated Muriate of Potash is a compound of Oxygenated muriatic Acid & Potash. When this substance is placed in the exhausted receiver in contact with heated Carbon it is decomposed. The products are Light, Carbonic Acid Gas, Muriatic acid Gas, Carbon & Potash muriated. It is evident then that Oxygenated Muriatic Acid is compounded of Light, Oxygen & Muriatic Acid[37]. Oxygenated Muriate of Potash is compounded of Oxygenated Muriatic acid & Potash. When Heated Carbon is placed in contact with this substance, it attracts the Oxygen of the Oxyg: Muriatic Acid combines with it & forms Carbonic acid Gas. The muriatic Acid & Light having no affinity for each other or for Potash are liberated in the gas form[.] The detonation & Corpuscular motion generated arise from the liberated Gases. The Detonations of all the oxygenated muriates may be similarly accounted for. All the Oxygenated Muriates are compounds of Muriatic Acid, Oxygen, Light & Bases. – It is probable light enters into the composition of many other acids, these acids I have not yet examined; but I intend shortly to engage in exp^{ts} upon them.

51 Light and Oxygen likewise combine with the metallic bases & form with them compounds, which have not been heretofore distinguished from the combinations of Oxygen. Those Oxyds in which I have ascertained the presence of Light are red Oxyd of Lead,

[37] Since Oxygenated Muriatic Acid is thus compounded it is evident that its present name is not expressive of its composition. The composition of the muriatic acid is unknown. Analogy induces us to suppose that it is a compound of some unknown base with Oxygen. The Oxygen^{d}: Muriatic Acid is a compound of Muriatic Acid with Light & Oxygen it shou[l]d be therefore called muriatic phosacid & its compounds phos'muriates.- From the mode of its generation it may be likewise induced that it is a compound of Muriatic acid, Light & Oxygen.--- Muriphosa[c]id.

Red Oxyd of Mercury, Orange colored Oxyd of Iron, Yellow Oxyd of wolfram &c[.] Red Oxyd of Lead is evidently a combination of Lead, Oxygen & Light for it affords Oxygen Gas on the simple application of Heat without Light. And when the white Oxyd of Lead is heated in contact with Oxygen Gas it becomes red & more ponderous, ie absorbs Light & Oxygen to which its fine color is evidently owing ----

When the red Oxyd of Mercury is formed by Heat it appears that no Light is given out in the process by the Oxygen Gas in contact. When it is formed from Nitric acid it combines with a portion of the Oxygen & Light of the Acid whilst the remaining Phosoxyd & Azote fly off in the form of Nitrous Oxyd Gas ---

It is evident then that the red Oxyd of Mercury is a combination of Mercury, Oxygen & Light. Its fine red color is evidently owing to the Light combined with it ----

The orange colored Oxyd of Iron is formed by the decomposition of Nitric Acid. Iron attracting a portion of the Oxygen & Light of the acid stronger than the Azote decomposes the acid. A portion of the Oxygen & Light combines with it to form oxyd of Iron & the remaining portion of Oxygen & Light combined with the Azote takes the form of Nitrous Oxyd Gas. The Oxyds of Tungsten, Manganese &c have evidently small portions of Light combined with their Oxygen for if muriatic acid be distilled from them it becomes Oxygenated which proves a subtraction of Light & Oxygen from them by the acid. ----

Phosmurioxid ac[i]d

52 It is probable that we shall detect Light in many substances in in [sic] which it has not been heretofore suspected. This important part of Chemistry has been entirely neglected. The Chemical Combinations of Light open an immense field for Exp^{t}. & speculation. That numerous Class of Substances which have heretofore been distinguished by the common names of Oxygen Attractors,[38] must now from the differences of their affinities be distinguished from each other. Some of them as Sulphur & Phosphorus are simple attractions of Oxygen or decomposers of Oxygen Gas. Others as Copper, Iron, Zinc Antimony &c under different circumstances attract, Oxygen & portions of Light with Oxygen. These &

[38] It is evident that the common name of Oxyd as applied to all the combinations of metallic substances with Oxygen & Light is very improper & if preserved in the nomenclature will be a source of error. Those bodies simply combined with Oxygen should be called Oxyds. Those bodies combined with Light & Oxygen should be called Phosoxyds as Phosoxyd of Mercury to express the Red Oxyd of Mercury. -----

metallic substances in general are sometimes decomposers & sometime partial decomposers of Oxygen Gas. Some substances attract Oxygen Gas or Light & Oxygen without decomposition as Azote, muriatic Acid, Mercury &c. By comparing the differences of the affinities of bodies for Light & Oxygen with their colors & by examining their colors before & after combination. We may probably discover an important part of the corpuscular Philosophy hitherto unknown. The causes of the differences of the sensations of Vision. ----

53 A combination of Light hitherto unknown, but by far the most important of any to Man is that with the venous blood in the lungs, This Combination I have demonstrated by direct experiment

THEORY OF RESPIRATION

It will be necessary before I advance my Theory to give a confutation of the Theory of Respiration now generally received.

In the Theory of Respiration now generally received Oxygen Gas is assumed to be Oxygen combined with Caloric. Since the Oxygen Gas made use of in Respiration is diminished & Carbonic acid Gas & water formed it is asserted that Oxygen Gas is decomposed in the lungs. It is said that a portion of the Oxygen combines with the iron of the blood oxydates it & gives it a vermilion color. Another portion combines with the carbon of the blood & of the pulmonary mucus to form the Carbonic acid Gas liberated in respiration. Another portion combined with the Hydrogen of the venous blood to form water. The Caloric which was combined with the Oxygen partly combines with the blood now increased in capacity & is partly liberated &c. Without considering my Exp^{ts} there are the following objections to this Hypothesis. 1st. Iron never decomposes Oxygen Gas at so low a temperature as 98° the greatest heat of the lungs & Oxygen Gas is never decomposed by iron without rapid combustion flame & great heat. 2dly Oxygen Gas is never decomposed by Carbon at so low a temperature as 98° & is never decomposed without the liberation of Light. 3^{dly}. There is never a decomposition of Oxygen Gas by the affinity of Hydrogen at so low a temperature

54 and this process never takes place without combustion. - This Theory of Respiration then is evidently false. It will appear from the following Experiments 1st that Oxygen Gas or Light & Oxygen is not decomposed in the lungs 2^{dly}. That both light & Oxygen combine with the blood in the lungs 3^{dly}. That Carbonic acid Gas & Water are both liberated from the lungs

either by the increase of temperature or by the superior affinity of Oxygen Gas for the venous blood ---

Exp^{t}. 28th. A Bottle containing twelve cubic inches & half was filled with very pure Oxygen Gas. I opened the medial vein of a healthy Man who had been accustomed to lose blood every spring. I directed the stream of blood into the Phial & instantly brought it in contact with the arm so as to exclude entirely external air. As the blood flowed in it became from a black to a bright vermilion color. When the bottle was half full it was closed, suffered to remain half an hour & then examined. The blood was of a bright vermilion & some drops of water were formed on the sides. When the bottle was immersed in water & the cork drawn some water rushed violently in & proved the absorbtion, or combination of Oxygen Gas with the blood. The Gas remaining in the Phial was examined & proved to be Oxygen Gas mingled with Carbonic acid Gas. NB whilst This exp^{t}. was preforming the room was darkened; but there was no luminous appearance in the bottle. – From this Exp^{t}. I concluded that Oxygen Gas is not decomposed by the venous blood; but that Light & Oxygen or Oxygen Gas combines with the blood in the lungs.[39] Since there is no liberation

55 of light, it is evident that the Carbonic acid & Steam must be liberated from the venous blood, to prove this more evidently I made the following Experiment ---

Exp^{t}: 29th. I filled a small sheeps bladder with the blood from the medial vein of a healthy Woman. This blood never came in contact with any air. The bladder was inserted in a vessel of water warmed to 112° & the gaseous products received by a pneumatic apparatus. They were carbonic acid Gas & steam.- <That all Land animals follow similar laws is evident - & Fish - then follow the exp^{ts} ---- & Zoophyta>

Respiration then is a chemical process. The combination of Phosoxyd or Light and Oxygen with the venous blood in the lungs & the liberation of Carbonic acid & steam[40]. ---

From the combination & decomposition arises an increase of corpuscular motion, which combined with that produced in the other chemical processes [illegible word crossed out] take place in the system & that generated by the reciprocal action of the fluids & solids, is

[39] The beautiful red of the arterial blood would alone analogically prove the existence of light in it.

[40] There are as well analytical proofs which I shall give in another place. In Land Animals the light combined with the system forms with Oxygen & Azote, Nitric Acid – in fish &&c it is liberated from hence fish when decomposing are luminous in the dark & list more of this is my essay on the Combinations of Azote.---

the cause of animal Heat. A Heat which the former Systems supposed to arise from the decomposition of Oxygen Gas. —

Oxygen & Light or Phosoxyd are both essential to organic Life. The perceptive & volitive powers owe their existence[41] to the supply of a certain quantity of blood combined with

56 light and oxygen to the brain. Some important change must be effected by this fluid (which is now a Phosoxyd with many bases) in the brain & nervous system. It is probable that a new combination takes place in the brain. The light may combine with some unknown substance to form the sensorial fluid. Whilst the oxygen combines with the <Azote> Phosphorous Carbon, Hydrogen &c of the blood to form <[three illegible letters] &c> compounds essential to organic existence. - The truth of falsehood of this supposition might be demonstrated by ascertaining the changes made in the arterial blood in passing thro' the brain. For this purpose it would be necessary to analise accurately, the arterial blood of the carotid arteries before their entrance into the brain & to estimate the changes made in it in its passage thro' the brain by examining the venous blood passing from the brain. –

It is probable that the electric fluid acts as a <compound> ~~stimulus on the irritable fibre~~ of Light & some unknown substance & since it acts as a stimulus on the irritable fibre, it may be the nervous fluid, ~~the principle of sensation & volition~~. This fluid formed by a chemical process in the brain ~~may be the~~ by the combination of Light with some unknown substance may be the principle whereby sensations are received & by whose stimulus on the irritable fibre the voluntary motions are preformed. --

But these are only suppositions, We are certain from experiments that Light & Oxygen act important parts in the animal Oeconomy: but we are ignorant of their mode of action & of the new combinations which take place in the system, these Exp^{t} & observations may perhaps determine. ----

57 So essential is Light to the existence of Man; but not to Man alone for all organic beings with which we are acquainted Terrestrial & Marine Animals & plants are alike unable to exist without Oxygen Gas or Light. We may consider the Sun & the fixed stars the suns of other

[41] There are a great number of Physiological facts which prove this, Animals die in a few minutes deprived of Oxygen Gas. Stricture upon the carotid arteries deprive animals of Sensation & voluntary power &cc.

worlds as immense reservoirs of Light destined by the greater creator of existence to diffuse over the world organisation & animation[42]. – And <Thus> will the laws of Gravitation as well as the chemical laws be considered as subservient to one grand end Perception & reasoning thus it will not appear impossible that one law alone may govern & act upon matter a law which might be called the law of Animation, a law directed by the will of the deity, tending to produce the greatest possible sum of perception, the greatest possible sum of Happiness.

Light is essential to the present constitution of our atmosphere[43] It attracts Oxygen from water, the marine Cryptogamia

Mem Darwin

58 vegetables &c & combines with it. This Combination of Oxygen & Light or Phosoxyd continually supplied to the atmosphere vitiated by respiration & Combustion preserves it in a state adapted to support Life. By producing heat in the atmosphere it is the cause of winds, which mingle the gases & every where maintain that equilibrium <of Oxy & Azote> in the atmospheric constitution which is essential to organic existence. -- Light is in a great measure the cause of general vegetation; which is in fact the decomposition of water & carbonic acid & water by the force of two attractions; that of the vegetable base for Carbon & Hydrogen & of Light for Oxygen[44] -- The colors of Vegetables Animals & indeed of all substances appear to depend on different quantities of Light & of Light & Oxygen combined with them. --

[42] It appears from astronomical observations, that all the planets have atmospheres.- Since Oxygen & Light are essential to the organic existence of all the beings on our globe & Since Light is supplied to the planets in the same manner as to our earth Analogy would induce us to believe (& we can here expect no other proofs) ~~&~~ that those atmospheres are similar in their composition with regard to oxygen Gas. The Lunar volcanoes will almost demonstrate that she has such as atmosphere. The solar atmosphere or the [word illegible] luminosa discovered by Cassini is of an amasing extent it is indeed supposed to extend to the plane of the earths orbit. May not this atmosphere be a compound of Oxygen with a very large proportion of Light. May not the sun be an immense Oxygen attractor. Then will the solar light arise from the decomposition of the Oxygen Gas in contact with the sun of which the oxygen combines with some bodies in the sun & the Light is liberated & this atmosphere continually wasted by decomposition may be partly supplied by the sun & partly from the planetary atmospheres which may as was before mentioned become so extremely rare & extend to so great a distance from there as to be attracted by the sun & to form a part of his orbit. **58** Or that peculiar disposition to receive a portion of the corpuscular motion of Light or to diminish the velocity of the vibrations appears to depend on the quantity of light or of Phosoxyd combined with them

[43] [NO NOTE]

[44] In fact plants will not grow without Light; plants when arrived at Maturity will continue to vegetate even when deprived of Light & will as is just going to be proved suffer great changes from the privation ----

When the Solar Light is excluded from vegetables they become white. This whiteness arises from a superabundance of pure Oxygen as the following Experiment will prove **Exp^{T}: 30** Two lettuces of nearly equal size were planted in the same soil. One was exposed to the solar Light, the other was covered with a close vessel, after remaining for some time they were examined. The one exposed was green the other perfectly white. Equal weights of the leaves were analysed. The white leaves affor<d>ed 5/15 more carbonic acid Gas & 3/15 more water than the green. The green afforded more Hydrogen Gas & residual Charcoal than the white. This Exp^{t}. proves that the whiteness of the one arose from a greater quantity of pure Oxygen, which in the analysis combined with Carbon to form Carbonic Acid & with Hydrogen to form Water. - When plants are exposed to the stimulus of light with but a small quantity of Carbonic acid

59 & water in contact to decompose, they become bright colored, orange, brown or red as the following Exp^{t}: will prove

Exp^{T}: 31ST. In a situation equally exposed to the solar light I planted two lettuces & two plants of wild sorrel. One of each kind was planted in moist clay; which had been before proved to be fit for vegetation. <The others> In dry sand mingled with a little clay. Those planted in the clay were daily watered those in the sand but just sufficient to preserve their existence. – After remaining in this situation for about a month of fine weather, they were particularly examined. The two vegetables planted in the clayey soil were of a fine green, large & flourishing plants. Those in the sand were of a ruddy brown & considerable [sic] smaller. By analysis the red afforded a small portion of Oxygen Gas; but in the green I could detect none, in their other principle they were as far as I can judge similar. From this it appears that light acts on vegetables as a chemical stimulus. It decomposes the water & carbonic acid in contact, by its attraction for Oxygen the vegetable at the same time attracting the Hydrogen & Carbon. When small portions of this Oxygen Gas combine with them they are green, when large portions they become red.- The beautiful color of flowers depend upon similar circumstances[.] Roses when carefully & entirely excluded from light before they begin to expand; become pale colored & almost white[.] By analysing those roses & comparing the products with those obtained from the red roses. It appears that the redness is owing to a greater proportion of Oxygen Gas in them. I have made experiments upon the marine Cryptogamia which prove that they are governed by the

60 same laws of color as vegetables. Like vegetables they become white when deprived of light and their colors are like those of vegetables proportional to the quantity of light combined with them. Fish & Zoophyta, the inhabitants of the ocean as far as observation can determine appear to be governed by the same laws of color. Those part of fish that are exposed to the light are uniformly colored, Brown, red, yellow, blue green &c. The backs, fins & indeed all the upper parts of Fishes are of these colors; but the belly which is hidden from the influence of Light is uniformly white. The Zoophyta can be bleached like plants & like plants become colored on a subtraction of their oxygen from Light. ----

Rational Analogy would alone induce us to suppose that the color of land animals depend on similar causes; but there are as well facts & experiments which will demonstrate this. - A certain quantity of Oxygen renders bodies white, almost all the Oxyds & Acids simply combined with oxygen are white. A certain quantity of Light & Oxygen renders bodies of different colors, Red as the rose, P. Oxyd of Mercury & P Oxyd of Lead, Orange colored as the Heliotrope, P Oxyd of iron &c Green, as the leaves of vegetables, P. Oxyd of copper. Those animals that are most exposed to the light are darker colored. Those which are least exposed to the Light are white & fair. Light then must act on animals as a chemical stimulus. It attracts the oxygen of the skin & the substance in the reticulum mucosum; which substance is chiefly carbon & Hydrogen with a small portion of Oxygen, When the Oxygen is subtracted there is a superabundance of Carbon.[45] From hence that

61 blackness so peculiar to the inhabitants of those countries, who are much exposed to the stimulus of light. The Inhabitants of the northern countries particularly those who are civilised & clad are much less exposed to the stimulus of Light. Hence the substance in the reticulum mucosum is combined with a greater quantity of Oxygen & is consequently whiter. Women are much whiter than men on account of their being less exposed to the stimulus of light. The parts of the body which are covered are much whiter than those, that are exposed.

[45] When the color of animals become hereditary, it requires a considerable time to effect the changes of color. Europeans are not made perfect negroes tho' much exposed to the stimulus of Light in the affrican countries for many generations and Negroes are not blanched except in a great length of time by the abstraction of Light - Thus the generating Mind which influences all the chemical changes which take place **61** in the animal oeconomy exerts its energies[.]

To prove more clearly this theory I have in a peculiar manner applied oxygen[46] to the skin; which was uniformly whitened by the application. -

I have blackened the skin almost instantly by an abstraction of Oxygen by Sulphuret of Potash.—The differences of the colors of the skin in quadrupeds depend on similar circumstances[.] The Hair of the animals of the polar countries are much white or paler than those of the Southern countries.[47] And Animals of the same kind are white in the north & south & dark in the equatorial countries as Bears, Foxes, Hares &c. And it affords a striking proof of the truth of this Theory that some of the northern Animals are black or brown in summer & white in winter. I have likewise made Experiments on the hair of animals & I have found in all cases, that a subtraction of Oxygen by any means renders the skin dark, that an addition uniformly turns it white ----

So much is the physical appearance of Organic beings & particularly of Man governed by the influence of Light

MEM shame &c

62 The different colors of the human complexion, the dark brown hue, the rosy tinge softened into white appear to depend on different quantities of Light & of light & Oxygen in the system. The dark brown ast[h]matic or scorbutic hue[48] appears to be owing to too small a quantity of Light & Oxygen in the system. The fine rosy flush of the Hectic countenance seems to be occasioned by too large a quantity of Light & Oxygen in the system[49] ---

A more intimate acquaintance [sic] with Chemistry & with the laws of organic Life will probably enable us to alter these two opposite deviations of the system from health. - It is almost certain from what we already know, that philosophical Physiology will have the power of effecting the greatest changes in the physical constitution of Man. When this Science is perfected it will be in the power of the Physician not only to restore health to the

[46] By the application of Oxygenated Muriatic acid or of diluted Sulphuric acid in the dark. These do not act on the skin in the light for Light attracts Oxygen stronger than the skin ----

[47] It shou[l]d be expressed than those of the countries under the equator --

[48] This doctrine of color will confirm D[r] Beddoes's ingenious Theory of Scurvy & consumption. The philanthropic exp[t] made by the D[r] on himself deserves the eternal approbation of Mankind – vide his letter to D[r] Darwin -- That exp[t] confirms this theory. The pale & shrunk experience of the skin in Typhus fever – the febris irritativa of D[r] Darwin proves the deficiency of light which is most certainly one of the principles of the seminal fluid in the system. ---------

[49] [No note].

impaired constitution but likewise to add beauty to the person, to picture on the pale cheek the rosy glow of Health & to bid the dull eye gleam with the lightnings of expression. ---

We cannot doubt but that the intellectual & moral ~~character of Man~~ as well as the physical Character of Man is influenced by Light. Not considered as a source of his numerous perceptions; but as a chemical Stimulus. The superiority of the nations inhabiting

63 the temperate Climes of Europe the abodes of Genius, Courage & Industry, has been uniformly too strongly marked to be attributed to any other cause, than the influence of Climate. We may venture to explain the causes of the influence of climate on physical principles[50][.] No physiological fact is better established than that stimuli of all kinds particularly those of Light & Heat exhaust the animating <power of the system> either by producing an increased action in the arterial & glandular system or by directly occasioning an expenditure of Oxygen. Is it not from a deficiency of this animating power, or irritability, that the inhabitants of the torrid zone are so much inferior to the rest of Mankind ---

When the animating power or irritability of the system is exhausted by stimuli of any kind as Light & Heat or corporeal exertion Mental activity will not exist. The stimuli of sensations & ideas not producing bodily exertions are the cause of Mental activity. A certain quantity of stimulus is essential to the activity.[51] The inhabitants of the equatorial climates having their irritability exhausted by external stimuli as those of Light & Heat are incapable of displaying the intellectual energies. The inferiority of the northern nations (an inferiority not now so strongly marked as formerly) is most probably occasioned by an exhaustion of their irritability by the stimulus of labor or from the want of those sensations which are the cause of mental exertion. If this is the case as appears probable Philosophy will doubtless have the power of destroying the influence of Climate, of breaking those chains which enslave so great a portion of Mankind & of dissipating that cloud

64 envellopes them in the night of ignorance.-

Science is as yet in her infancy; but in her infancy she has done much for Man – Those discoveries so beneficial to Mankind which have been made heretofore have been generally effected by the energies of individual Minds. What hopes may we not entertain of the rapid

[50] No physiological fact is better established.

[51] & of animating power

progress of the happiness of Man when Illumination shall become general, when the united powers of a number of scientific Men shall be employed in discovery. Every thing seems to announce the rapid advance of this period of improvement. The time is approaching when Despotism & superstition those enormous chains that have so long enfettered Mankind shall be annihilated when liberated Man, every barrier to his <amelioration> improvement being destroyed, shall display these mental energies for which He was created.

At that period Nations shall know, that it is their intent to cultivate Science & that the benevolent Philosophy is never separated from the happiness of Mankind. ---

June, 1798. Humpʸ Davy

[65 blank page]

[66] Humphry

From you orient azure sky

The gloomy shades of darkness fly

The Trembling

The trembling waves reflect the

lucid ray & ore the mountains

~~trembling hills~~

~~the lucid ray~~

Acknowledgements

Above all I am grateful to The Royal Institution of Cornwall (RIC), Courtney Library, for permission to work on and publish this manuscript and to Angela Broome, Courtney Librarian and Archivist, for facilitating access and providing information on provenance. I am also grateful Jan Golinski for many helpful comments on an earlier version and to J.V. Field for advice on various issues raised by the text. I also thank the following for permission to study manuscripts in their possession: The Royal Institution of Great Britain (RI), Cornwall Record Office (CRO) and the Library of Birmingham (LoB).

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