On the history and prehistory of CO_2

Jens Soentgen

Abstract I will trace the little known prehistory and parts of the better known history of CO_2 by investigating some of the names it has been given from Antiquity to the present day. In Antiquity, the words pneuma or spiritus letalis designated both a supernatural force and an exhalation that emanated from certain caves. We will see how CO_2 gradually came to be regarded as something natural, a gas and then substance.

Keywords Carbon dioxide · Gas · History of science · History of religion · Global warming · Greenhouse gas

Mazuku

Lake Nyos is among the most beautiful of the crater lakes in western Cameroon's volcano region, formerly called the "good lake" by locals. During the night of 21 August 1986, however, something terrible happened, which the late American anthropologist Eugenia Shanklin later described from the perspective of a survivor (see Shanklin 1988, p. 12): "At SuBum, close to the village of Nyos, one man heard his 9-year-old daughter choking and he got up to go to her, but before he reached her room he fell unconscious onto the floor. When he awoke, dazed and sick, he crawled into bed beside her and only realized she was dead hours later (…) There was a burning sensation in his lungs; he drank all the water and tinned milk in the house, then climbed on his motorcycle and made the 20 km ride to Wum. The road was littered with bloated human and animal carcasses. To pass, he had to move the bodies of friends and neighbours, but the worst part was the overwhelming silence: in one of the most fertile valleys of the volcanic uplands, an area well-stocked with bugs of every variety and vocal persuasion, not an insect remained." Upon reaching the city of Wum, he alarmed the police. Several policeman and a priest then made their way to the little village on the lake, doubling back the way the survivor had come. But as they

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approached the lake, it occurred to the officials that whatever had killed all these people and cattle might still be in the area. They stopped and decided not to continue. Only the priest insisted they continue onto the lake since it was a matter of saving human lives. And so he continued on, alone.

In all the villages on the lakeshore there weighed an oppressive silence. Most of the houses were closed up. There was only motionless silence, as if it were still night time. In front of other houses dead families were crowded together.

Later the priest, the Dutch missionary Father tenHorn, would say, it looked as if a neutron bomb had hit: "Little damage to property, but an almost total destruction of life." This remark would soon pass from mouth to mouth.

Even today the rumor persists that the American and Israeli military detonated a neutron bomb at Lake Nyos (Shanklin 1988; Shanklin 2007, pp. 169–171; Sinjoh 1997, p. 22).

However, investigations by European geologists come to a different conclusion: according to them it was a massive carbon dioxide bubble that rose from an underground magma chamber which had formed under the lake bed, and had finally, perhaps triggered by a mudslide, escaped, spreading out over the shore and killing people, animals, birds, and even insects. Altogether the catastrophe caused at least 1,765 deaths and killed 3,000 head of cattle in addition to countless goats, sheep, and chickens.

Carbon dioxide emissions occur in several places in Central Africa. Often they are referred to by the Swahili word "Makuzu", "evil wind". But in the Nyos region scientific theories attributing the event to natural causes never really caught on. Rather, a female spirit called Mami Wata, who lived in the lake, was believed to have been associated with the catastrophe. The poet Bole Butake, shaken by the tragedy, wrote a play with the title "Lake God" in which he explicitly refuted the notion that a gas could be responsible for the event, pleaded for a return to the old beliefs and demanded offerings be made to the water spirit (Butake 1986; Asong 1987).

Pneuma

The terrible events around Lake Nyos in Cameroon took place in the twentieth century. However, it provides a sense for the circumstances and locations in which people probably originally encountered CO_2 and how they might have described these experiences. The local population's rejection of explanations that the catastrophe had been triggered by a *gas* (Shanklin 2007) shows that *this* interpretation is in no way obvious.

It is only as of fairly recently that we even "know" that things such as a "gas" even exist. The designation "gas" is around 350 years old, and references to carbon dioxide (or carbonic acid, see below) date back only around 200 years. Strictly speaking the history of carbon dioxide is limited to these 200 or 300 years, and it is a history that is limited to the west. For many people in other areas of the world there are no "gases", and thus no carbon dioxide.

One can surmise that the first names of that which we call CO_2 were names of gods or demons. They were undoubtedly often local names of which very few are known to us today, such as that of *Mephitis*, an Italian deity who was worshipped in regions where there were once emissions of CO_2 and gaseous sulfur compounds. It is not very easy, in retrospect, to establish a connection between such names and what we call CO_2, since these names are part of an entirely different frame of reference. Hence it cannot be assumed that such names consistently refer to what we today call CO_2.

If one investigates the prehistory of CO_2 one treads on shaky ground. One must look at the sources one-by-one and examine the descriptions of *places* where carbon dioxide was probably emitted. Even so, much still remains conjecture, for archaeologically carbon dioxide, as opposed to other substances, is not detectable. It leaves no traces. We are on the trail of a phantom, a specter, whose presence is suspected but never certain.

What are these places where carbon dioxide appears in high concentrations? Plinius (23–79) notes in his *Naturalis historia* (Vol. XXIII, Chapter xxxi)[1] that in fermentation cellars workers, who descent in vine barrels sometimes lose consciousness or even die. But he ascribes this to the strength of the *faex vini* (yeast) and concludes, that this yeast must be a powerful pharmakon. Vitruv (born 84 AD), too, reports in his *De Architectura Libri Decem* (Liber octavus VI, 12–13) on the dangers of digging deep into the ground. If workers, he says, dig a deep well, a portion of the "air" that is passing the ground might suffocate them: "aerisque spiritus immanes, qui, cum graves per intervenia fistulosa terrae perveniunt ad fossionem puteorum et ibi homines offendunt fodientes, vi naturali vaporis obturant eorum naribus spiritus animales" In order to prevent this, he recommends lowering a lit lantern into the shaft. If the flame remained alight, then there was no danger. But if the flame was extinguished by, as he put it, the heavy effusion of vapors, then it was necessary to dig additional shafts left and right of the well shaft. Thus the vapors could escape "as if through nostrils".

Other places where CO_2 was present were deep holes in the ground such as those in volcanic areas. In every volcanic eruption, besides dust, magma and noxious gases, a large amount of carbon dioxide is released. And even when a volcano is not active carbon dioxide is emitted from the earth all the same. The deeper one digs into the earth, the more likely it is that one will encounter carbon dioxide, for it rises upwards through cracks that extend down to the hotter layers of the Earth. In addition, CO_2 often occurs in increased concentration in caves. Geologically most caves, especially limestone caves, owe their existence to CO_2 (see Herman 2005). As a rule they are created where CO_2-rich, and therefore, acidic (thanks to the formation of carbonic acid) and chemically aggressive water hollows out rock and forms pockets or caverns. This hollowing out of rock would be practically impossible without a high concentrations of CO_2. Even if the flow of water eventually dries up or seeks a different course, the air in the cave often remains CO_2-rich. This is because, for one, CO_2 continues to emanate from the depths of the earth and reaches the cave through cracks, and for another, since the cavern is closed off, it cannot dissipate or be otherwise eliminated—for there are no plants that would convert it into oxygen. Thus, CO_2 accumulates in caves, especially in the deeper chambers. CO_2 poisoning is still today one of the greatest dangers for spelunkers, cave visitors and for others who work underground professionally. In the German mining jargon it has therefore retained its traditional name: "heavy air" (Schwere Wetter); for unlike the better known "mine gas" (methane—Schlagende Wetter) that rises, it accumulates in the deeper zones.

Springs and caves are often treated in the ancient literature as an entrance into the realm of the dead, which the Greeks as well as the Romans conceived of as the Underworld, a

[1] Due to the existence of numerous editions, the classical literature cited here will not be referenced by page numbers, but rather by relevant chapter and paragraph.

place where the Shades live, ruled by the dark god Hades who rides a golden carriage. The dead were transported by boat into the underworld via underground rivers. The ferryman, Charon, was according to ancient descriptions a cantankerous fellow with unkempt hair and greenish skin who beat the souls out of the dead with a hammer.

The classic entrance to the Underworld is Lake Averno by Naples, a former volcanic crater that lies in the volcanically highly active area around Mount Vesuvius. In the immediate vicinity of this lake, Aeneas, the Roman hero, meets Sibyl to ask her how to get to the Underworld where he could see his father. In response to Aeneas' question Sibyl points to a grotto near Lake Averno, but she warns him that a "poisonous cloud" bars the entrance. (Virgil, Aeneid, Sixth Song).

Several times in the Sixth Song of the Aeneid poisonous vapors are mentioned, and also in the grotto of Sybil these seem to be seeping forth. Did carbon dioxide come into play here? Could this have something to do with Sybil's ecstatic agitation? Indeed in Virgil it is mentioned several times that she wheezed and breathed rapidly—typical symptoms of carbon dioxide poisoning but also of other types of poisoning. In the text itself the phenomenon is of course interpreted completely differently, namely as the presence of the god Apollo who embraces his priestess.

At another, still older site, namely at Delphi, key sources also lead one to think that carbon dioxide poisoning might be at play. Thus, several sources report that the oracle of Delphi, the most famous of all antiquity, goes back to a discovery by a goatherd named Koretas. He is supposed to have observed how his goats began to behave strangely as soon as they approached a crack in the earth. They sprang about and bleated out strange sounds. As the goatherd stepped up to the place, he was overcome by a prophetic spirit and could foretell the future. His neighbors experienced the same, and finally pilgrims came from everywhere; some, however, in their prophetic ecstasy fell into the hole and never again surfaced. As a result, the people of Delphi decided to choose a woman from their midst to serve as oracle for them all. The crack in the earth was covered with a tripod seat, on which the prophetess was enthroned and where she would fall into a trance, allowing Apollo to possess her spirit. This practice was continued even after the temple was built.

At the end of the nineteenth century when the Temple of Apollo was excavated on the side of Mount Parnassos below a peasant village, the team found a rectangular structure of rows of columns; statues and walls came to light. However, they searched in vain for a smoking crack in the Earth. On the other hand, there are several archaeologists who to the present day insist that carbon dioxide played a role in the ecstatic behavior of the Pythia, the latest addition, published in 2008, being a thorough study by Piccardi (2008). In Piccardi's view it was a mixture of hydrogen sulfide and CO_2, as a result of an earthquake, that for some period of time seeped out at the Delphic Temple of Apollo. He presents a number of geological indications that are not implausible, but also not definitive enough to be considered absolute proof. Perhaps it really was the god himself, and not the CO_2, that was responsible for the prophesies.

We have only a few reliable sources about what really happened at Delphi. The oldest reference is the Homeric Hymn to Apollo, which describes how Apollo slew a dragon in the vicinity of Delphi. As its corpse rotted in the sun, intoxicating vapors arose from its decomposing body. Since then, prophesies occurred at this location.

Among the later authors only Plutarch (45–125) is generally considered a reliable witness, since he himself served as a priest of Apollo at Delphi for several years. And in fact Plutarch also comments on a remarkable phenomenon in connection with the oracle that suggests CO_2. Towards the end of his writings on the demise of the oracle (*De defectu oraculorum*) (after 443 E) he refers to a "mantikon pneuma", a prophetic breeze or vapor

that arose from the earth; he also refers to the emission of vapor (anathymíasis) or a stream, a flow (rheuma). Plutarch was not a Stoic philosopher. Nevertheless his term anathymíasis does not refer to purely material objects in the present-day sense; it could also be used to refer to the soul or the spirit (see Fernandez 1994).

Let us dwell a little longer on the ancient descriptions of caves. Thus, the ancient travelogue author and geographer Pausanias (circa 115–180) reports with regard to the Cave of Trophonius (in the 9th book of his Description of Greece, Chapter 9.39 ff), an oracle located in Boiotia, a mountainous region in Greece. Trophonious was a god of the underworld, a son of Apollo. He had built the temple at Delphi together with his brother Agamedes, so the legend goes, but eventually struck down his brother and fled to that cave near Lebadeia (today Livadia), where he died. Trophonious is a rather minor figure in ancient Greek mythology. However, Trophonious gave those who visited him the ability to see into the future. Whoever visited the oracle had to carry out extensive preparations. Thus, he first had to stay several days in a house dedicated to the *Agathon daimon* and to *Tyche*. During this period he had to undergo ritual cleansings in the River Herkyna. Before the descent into the cave several animals had to be sacrificed, the flesh of which nourished the suppliant. At each sacrifice priests were present who examined the entrails. Finally, after further preparations, the oracle seeker went into the cave that was on a mountain. There, he let himself down on a ladder into a cavern and finally wedged himself into a narrow crevice in the rock into the holiest of holies. Here some now heard something, as Pausanias reports, others however, saw something. Finally, however, it seems that most were almost unconscious. And herein lay the danger of the situation, for the oracle seeker had to extricate himself from this narrow crack. Up above he would be received by the priests, set on the throne of Mnemosyne, the goddess of memory, and questioned. Finally he would be turned over to his family and bit by bit recover full consciousness once again. Also here one can assume that the oracle seeker suffered from carbon dioxide poisoning (as did for example Lersch 1863, p. 25). There are some arguments for this assumption, for among the known symptoms of such poisonings (that can already appear with exposure to CO_2 concentrations of four percent) is, besides delirium, cramps, dizziness and strong mental excitement, is ringing in the ears (Lehwess-Litzmann 1943, p. 42).

Spiritus letalis

The location of some of these ancient caves is today unknown. In others, the location of which is known, there is today no measurable increased carbon dioxide concentration. This is not surprising, for just as many springs that are mentioned in the ancient literature have since then dried up and others newly appeared, so too can gas sources quite easily disappear or even reappear again elsewhere. In fact they do so even more easily.

An exception is the *Grotta del Cane*, the so-called Cave of the Dog, found in the vicinity of Naples, not far from what today is a dried up lake, the *Lago di Agnano*. It is probably the one to which Plinius refers in the second volume of his *Naturalis Historia* (Chapter 95), in which he counts certain remarkable caves among the "wonders of nature". Particularly in the area of "Sinuessa" (today ruins near Racco die Mondragone) and "Puteoli" (today Pozzuoli), he notes, there are caves which breath forth a "deadly mist" (spiritus letalis). Seneca also writes in the sixth book of his *Naturales Quaestiones*, which in fact is dedicated to the earthquake, about holes that exude a poisonous vapor (foramina

pestilens exhalatur vapor, Chapter 28). Seneca adopted a theory of the stoic philosopher Poseidonios (135–51 BCE), who said, that earthquakes had much to do with air and wind—they were seen as a kind of flatulence of the earth. (Reinhardt 1921, pp. 158–162).

The Cave of the Dog that Plinius describes still exists today. The designations *Spiritus Letalis* (lethal spirit), *Vapor Pestilens* (pestilent vapor) or also *Spiritus Mortiferum* (murdering spirit) already express a certain distance to the eerie phenomenon: no longer associated entirely with the divine, the phenomenon, as the designations indicate, is conceived of as something air-like. A decisive abstraction was therefore, made; the name no longer supplicates but describes. The next term that refers to CO_2 is constructed in a similar way, but it elevates this abstraction, without becoming entirely dissociated from religion. It is the designation *Spiritus Sylvester*, which was coined by John Baptista van Helmont.

Spiritus sylvester

The term gas was, as already mentioned, introduced by the Flemish doctor, alchemist, and mystic Johann Baptist van Helmont (1579–1644); it appears for the first time in a collection of his writings called *Ortus Medicinae*, published in Amsterdam in the year 1648. He goes into his new theory most extensively in the treatise "The fiction of Elementary Complexions and Mixtures". He describes the experiments that he had done heating charcoal in a closed vessel thus: "Suppose thou, that of 62 pounds of Oaken coal, one pound of ashes is composed: Therefore, the 61 remaining pounds, are the wild spirit, which also being fired, cannot depart, the vessel being shut. I call this Spirit, unknown hitherto, by the new name of Gas." (van Helmont 1664, p. 106).

The term gas is one of the most important advances in scientific terminology in the history of chemistry. With it, it was possible to study the air, to categorize and to scientifically study the atmosphere. Van Helmont had no experience with asphyxiating caves, there was nothing like that in the Flemish Netherlands. But he had preoccupied himself extensively with combustion and fermentation processes. In the course of his studies he noticed that when oakwood charcoal is burned a very large volume of an invisible substance is set free, and this can, if kept in a tightly closed container, develop significant forces. Also in the fermentation of wine something was set free that pressed with force against the barrel plug, if the barrel was tightly closed. CO_2 has tremendous power! This is evident in every bomb that explodes, and also quite evident to anyone who has opened a bottle of champagne. Van Helmont dubbed that which was thereby set free, because of this energy, the name Spiritus Sylvester, "wild spirit", and said, generalizing, that it had to do with a "gas". This word he derived from the Greek word "chaos". One recognizes the connection if one pronounces the word correctly—"chaos" is pronounced in Dutch as "chaas", which is similar to the ancient Greek pronunciation of the word "chaos", with a soft "ch" and not, as has become conventional, "Kaos". Paracelsus often speaks of chaos, and it has therefore, often been maintained that he was van Helmont's inspiration to coin the term, since van Helmont was an avid reader of Paracelsus. In fact, however, the chaos terminology in Paracelsus is too inexact to really be considered a precursor (cf. Pagel 1962).

Van Helmont was the first to regard the substance set free during heating or fermentation as something totally different from the surrounding air and from water vapor. Moreover, gases were for him very special substances. Van Helmont believed that the gas

he had before him constituted the innermost principle of the body, something like its living spirit, which drives it from within. Precisely for this reason gases could be especially dangerous to people, and in this regard van Helmont explicitly mentions not only the Cave of the Dog, but also the dangers lurking in fermentation cellars and in mining pits. Gas inhaled could kill much more quickly than poisoned food or drink. A characteristic that van Helmont believed to be due to the fact that gases had a direct effect on the living spirit of a human being. Thus, in his conceptual framework gas remained something sinister, it still being a concept related to the "pneuma" (spirit) of antiquity. Like many alchemists (Schütte 2000, pp. 70–74, on van Helmont ibid., pp. 468–473) van Helmont, too, was very much influenced by stoic philosophy, which asserted that the divine was strictly speaking material. God permeates the material as fiery breath, as pneuma (Pohlenz 1959, pp. 82–93). Van Helmont thus regarded his gas as something that was at least semi-divine. It was for this reason that it was not to be contained in vessels and why it could not return to a solid state. It is therefore, too short-sighted to regard van Helmont's terminology simply as a predecessor to our own. What he understood to be a gas was significantly shaped by and linked to the terminological constructions of late antiquity.

Fixed air

With his investigations van Helmont opened up to aspiring science a tremendously broad, new horizon, and profoundly influenced, yes, inspired subsequent generations. Especially van Helmont's conception that gases existed inside solid bodies as their "co-existential spirit" exerted great influence on the conceptions of later generations. They repeated van Helmont's experiments and invented new ones. Others, such as the preacher Stephen Hales (1677–1761), who, like so many English clerics of that time, also knew how to experiment, coined new names. Hales wrote in his work *Vegetable Staticks*, published in 1727: "From a piece of heartwood of the oak was released 216 times its volume of air. 216 cubic inches of air, compressed into the volume of a cubic inch, if it was contained inside, would press against the six sides of the cube with a force equal to 19,860 pounds, a force that would be sufficient to tear apart the oak in a monstrous explosion." (Hales 1731, p. 215) Since oaks do not normally explode, however, Hale concluded that whatever type of air this might be must be somehow fixed there.

Joseph Black (1728–1799), another English natural philosopher, studied that air more closely and called it "fixed air". Carbon dioxide was known by this name for the next few decades. Only later would the properties of this new type of air be more exactly understood.

Joseph Priestley (1733–1804) was among those who concerned themselves with this fixed air particularly intensively. In 1770, Priestley began his work with gases. He furthered the investigations of Hales and merely 2 years later, in 1772, presented his first comprehensive report to the Royal Society.

Priestley had learned that fixed air was created by both respiration as well as combustion and was a by-product of many other natural processes, such as of brewing beer. In the vicinity of Priestley's residence there was a brewery, and it was from there that he got his fixed air.

These studies were motivated by a specific question. Priestly observed, as many before him had as well, that his "fixed air" (he also spoke of "mephitic air") was produced not only in beer brewing, but also could be detected in places where many

candles burned or where many people breathed. If one burns a candle in a closed container the flame is soon extinguished, just as it is when a candle is doused with carbon dioxide, The air in which the candle has gone out can also no longer sustain animals; mice asphyxiate in it. It is "rotten", spoiled, as Priestley thought, by an excess of phlogiston, which this air had had to absorb. Priestley was an adherent of Phlogiston Theory, which he never rejected (Soloviechik 1962). And so he understood his "fixed air" to be a kind of dephlogistized air. How, Priestley asked himself, could this decayed air be restored? Could one transform the "fixed air" back again into good, breathable air? Priestley was not the first to pose this question. In his time there still was no real university research, but a great many opinionated lords and idle rich, who in their amply available free time concerned themselves with all kinds of possible and impossible questions. Thus, a certain Count of Saluce opined that one could renew such "rotten air" either by cooling it or by more or less gently massaging it in a pig bladder, thus "bringing it back to life". The conscientious Priestley examined all these recommendations. But not being able to confirm effectiveness of these recuperative methods for the air in his experiments, he tried something new.

And here a very special plant, mint, comes into play. Apparently Priestley must have thought: if people chew mint to make their bad breath sweeter smelling, then perhaps this plant can refresh the decayed air!

Back then, mint grew in every English kitchen garden. To be sure, one no longer crowned oneself, as in ancient Greece, with mint sprigs, but it was drunk as an infusion, used as an herb in cooking and had many uses as a home remedy.

So Priestley put a sprig of mint in one of his glass jars that was filled with decayed air and added some water so that the plant would not wilt right away. The mint and its gentle, seductive fragrance became the Muse of his scientific work, bestowing upon him one of the most important insights of modern science:

"Accordingly, on the 17th of August 1771, I put a sprig of mint into a quantity of air, in which a wax candle had burned out, and found that, on the 27th of the same month, another candle burned perfectly well in it." (Priestley 1774, p. 52). Mint was thus capable of making asphyxiating, dangerous air breathable again! The little green cutting thereby did something more glorious than the girl in the fairy tale who spun straw into gold. Curious, as Priestley now was, he tested to see if it was only the fragrant mint that had the power to make bad air good again, or if there were other herbs that could serve the same purpose. He tested his entire herb garden, whereby he first examined a near relative of the mint, also fragrant, lemon balm. Finally he began to try his experiment with a foul-smelling plant. And, indeed, this too turned deathly air life-giving! So the effect was not a matter of the plant's pleasant smell! Priestley cleverly generalized that all plants could renew dead air—as long as they are growing. That which the animals and man use up they silently renew—hour by hour.

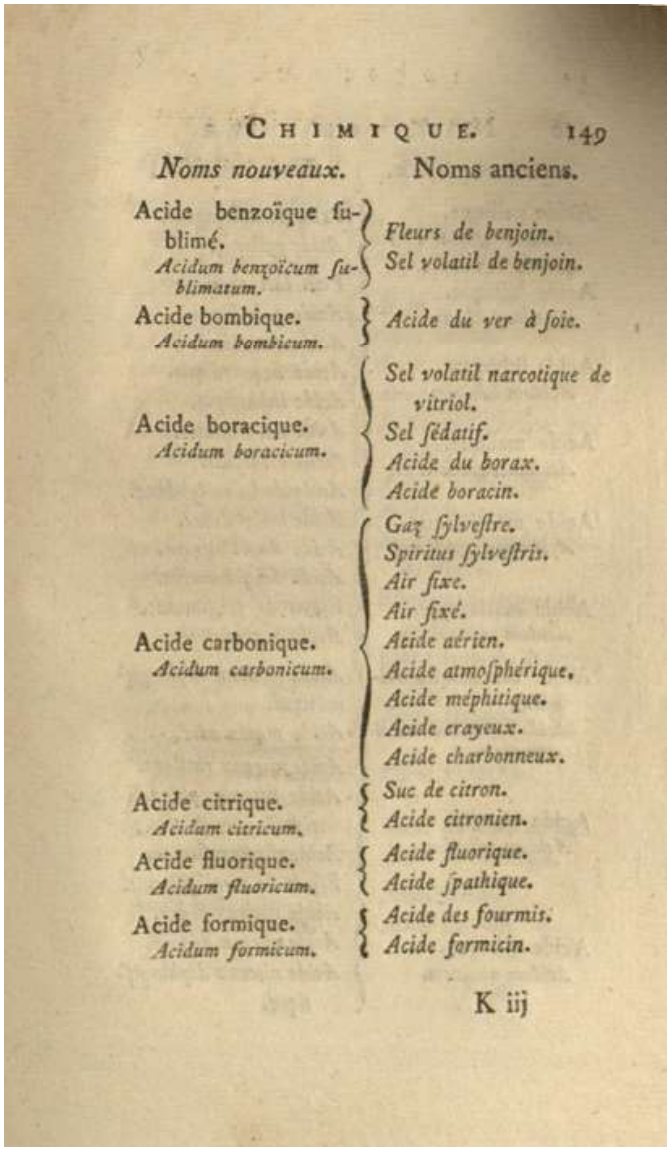
His contemporaries immediately recognized the enormous implications of his discovery. And because back then scientists were pious, they recognized in this discovery once more the deep wisdom of the Creator, who in his unfathomable goodness had taken precautions from the start that the air which sustained animal and man would not at some point run out. Thus, he had for this very purpose created plants: thanks to them there would always be sufficient air to breathe! When the Royal Society in London, one of the oldest and most important scientific organizations, awarded Priestley a medal of honor, the president, the otherwise gruff and not at all lyrical John Pringle (1702–1782), held a moving, and for the history of CO_2 most informative speech on Priestley's achievements: "From these discoveries we are assured that no vegetable grows in vain, but that from the

oak of the forest to the grass of the field, every individual plant is serviceable to mankind; if not always distinguished by some private virtue, yet making a part of the whole which cleanses and purifies our atmosphere. In this the fragrant rose and the deadly nightshade co-operate: nor is the herbage, nor the woods that flourish in the most remote and unpeopled regions, unprofitable to us, or we to them, considering how constantly the winds convey to them our vitiated air, for our relief, and for their nourishment." (Pringle 1783, p. 34 ff). Even the poisonous nightshade is not merely poisonous, is not only a work of the devil, but has a place in God's design! For even it carries out an imperceptible, but necessary task in which it transforms air that is deathly and spent into air that is fresh and life-giving.

Now Priestley was not only a scholar, but also had a knack for technical developments. Since he knew that the gas to which the medicinal properties of a number of mineral springs were attributed was the very same stuff as his fixed air, he experimented with how one could artificially produce such mineral water. And he succeeded, more or less by simple shaking, which pressurized fixed air in water, thereby making the first artificial soda water. With that he became a pioneer of the soft drink industry. His work on artificial "spa water" he dedicated to John Montague, the Earl of Sandwich (1718–1792), the inventor of the sandwich that was named after him. It is a remarkable situation that in this dedication two inventions were brought together that so strongly influence our present-day eating habits—the sandwich (ancestor as it is to the hamburger) and mineral water (ancestor as it is to the soft drink). For Priestley, however, the Earl was not important as the inventor of the sandwich—undoubtedly he knew nothing of this invention of his Lordship. It was much more the Earl's role as Commander-in-Chief of the British Navy that prompted this dedication. For Priestley was convinced that his artificial soda water was the solution to the most serious problem that the British ships on the high seas were beset with, namely scurvy. Priestley believed in all seriousness that his soda water could prevent this disease. Now indeed, carbon dioxide is in fact a useful additive to water because it kills germs, and the water therefore, stays fresh longer and is made healthier. In preventing scurvy, however, it has no effect.

The three names of CO_2 listed up to now—*spiritus letalis*, *spiritus sylvester*, and *fixed air* have one thing in common: they are anchored in actual experience. In these names there is indeed an element engendered that is somewhat exotic, dangerous, and in a sense sensational, but none the less fundamentally belongs to everyday experience. The term *fixed air*, on the other hand, already refers to a greater degree of laboratory experience. That in certain things a type of air is in a sense bound up, and which can be set free by heating, can be indeed be accepted, but it can be much better understood with experimental apparatus. The anchor in the everyday real world was reeled in, however, at the turn of the nineteenth century.

The new name of CO_2 was one that was anchored in a totally different context, namely in a professional theory. "*Acide carbonique*" (carbonic acid) is a name that not only requires knowledge derived from laboratory experience, but also knowledge of a theory that coordinates countless facts and can therefore, only be understood by a specialized professional group. Names are routes that lead one to a thing. But, as in a city, one can reach one and the same thing from totally different starting points or via different routes. So where did this term come from? (Fig. 1).



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Noms nouveaux.	Noms anciens.
Acide benzoïque sublimé. *Acidum benzoïcum sublimatum.*	*Fleurs de benjoin.* / *Sel volatil de benjoin.*
Acide bombique. *Acidum bombicum.*	*Acide du ver à soie.*
Acide boracique. *Acidum boracicum.*	*Sel volatil narcotique de vitriol.* / *Sel sédatif.* / *Acide du borax.* / *Acide boracin.*
Acide carbonique. *Acidum carbonicum.*	*Gaz sylveſtre.* / *Spiritus sylveſtris.* / *Air fixe.* / *Air fixé.* / *Acide aérien.* / *Acide atmoſphérique.* / *Acide méphitique.* / *Acide crayeux.* / *Acide charbonneux.*
Acide citrique. *Acidum citricum.*	*Suc de citron.* / *Acide citronien.*
Acide fluorique. *Acidum fluoricum.*	*Acide fluorique.* / *Acide ſpathique.*
Acide formique. *Acidum formicum.*	*Acide des fourmis.* / *Acide formicin.*

K iij

Fig. 1 A revolutionary moment in the history of CO_2: A multitude of former names is reduced to the new name acide carbonique. (from *Méthode de Nomenclature Chimique*)

Acide carbonique

Like all other substances, Priestley's fixed air soon got caught up in the theoretical turmoil brought on by French chemist Antoine Laurent Lavoisier's (1743–1794) "antiphlogistic chemistry". In this new and revolutionary chemistry the well-to-do citizen and tax collector Lavoisier no longer explained combustion processes with the help of an invisible substance called phlogiston that was ostensibly released during combustion, as had previously been the case, but rather posited that combustion in fact involved a chemical synthesis in which oxygen is added. Lavoisier had already published this new theory in 1777.

It only became generally accepted, however, with the famous work *Méthode de Nomenclature chimique* (Method of Chemical Nomenclature) that Lavoisier published together with his colleagues Fourcroy and Berthollet, who were already supporters of his new theory. This work introduced new names for many chemical substances—names that were not simply new designations, but rather expressed the experiences that chemists had had with specific substances (Ströker 1982, pp. 271–281). This book that occupies a singular place in the history of chemistry also did away with the colorful names by which

our invisible gas was known. In their place appeared a purely chemical designation that only took into account the substance's chemical composition: *l'acide carbonique*, carbonic acid. No distinction was made between the gas and its dissolved state in water (Lavoisier 1787, p. 149, in the English edition published in 1796 he speaks of "carbonic acid assuming the state of gas"). A colleague of Lavoisier, a certain Monsieur Hassenfratz, also gave it a graphic symbol, but this was not generally accepted.

When at the beginning of the nineteenth century Jöns Jakob Berzelius (1779–1848) succeeded in creating a system of convention which permitted the notation of chemical substances, and which was so easily adapted to the requirements of research that it finally was accepted internationally, he also transformed carbon dioxide. He wrote: "The chemical sign expresses always one volume of the substance. When it is necessary to indicate several volumes, it is done by adding the number of volumes … the sign …for carbonic acid (is) C + 2O" (Berzelius 1814, p. 51, reproduced in Klein 2003, p. 10). Since this notation was sometimes cumbersome, he conceded that it could also be abbreviated as $C\overset{2}{O}$. Berzelius' suggestion was initially ignored, but in the course of the nineteenth century ultimately did manage to become established convention (Klein 2003, p. 14 ff). Justus von Liebig used Berzelius' notation, but instead of superscript used subscript (see Klein 2003, p. 78), a practice that finally became the accepted convention. So, after countless transformations, the symbolic form by which we know carbon dioxide today came into being: CO_2. It is, besides H_2O and the benzene ring, one of the three chemical formulas that is popularly known worldwide.

With this formula the invisible, furtive and rather uncanny "spirit" was given his internationally valid identity that turned him into an ordinary substance within the modern system of chemical substances. The formula revealed its origins, in a certain sense its lineage that explained from what it was produced: from carbon and oxygen. CO_2 is therefore, not only a name, but a precise statement about the substance. This name, this statement constituted the point of departure from which all further investigations of the substance were carried out. The subscript number two thereby referred to the quantitative element that had been determined through experimental practice. Yet to outsiders who do not know what the C, the O and the two refer to the name remains an undecipherable hieroglyph.

Thus, the designation indicates also to a dividing line—one that separates chemists, i.e., those with mastery of the notation who know what is meant and why it is so designated, from the laymen. But yet precisely because this formula is enigmatic to many people, it can also become charged once again with mythical content. It can be retransformed into something ominous. This is in fact how the term is used today in many public debates, as especially in Germany, where the fact, that CO_2 is a greenhouse gas has led some to think of it as an air pollutant or even as a "climate killer" (Klimakiller).

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