Chapter Two

Overall Views on the Formation and Constitution of the Earth's Atmosphere

2.1 The account of the formation of aeriform elastic fluids, or gases, that I have just presented sheds great light on the way in which the atmospheres of planets, in particular the earth's, were formed in the beginning. It is clear that our atmosphere must be a product and an amalgam of (1) all evaporable substances or, better, all substances which remain in an aeriform state at the temperatures in which we live, and at a pressure equal to a column of mercury 28 inches high; and of (2) all fluids or solids that can be dissolved in this assortment of different gases.

2.2 To better fix our ideas concerning a matter which no one has yet considered carefully enough, let us imagine for a moment what would happen to the various substances which compose the earth if the temperature were to change abruptly. Let us imagine, for example, that the earth were suddenly transported to a much hotter region of the solar system, perhaps somewhere near Mercury, where the normal temperature is probably much higher than that of boiling water. Before long, water, all fluids which evaporate at any temperatures close to that of boiling water, and mercury itself, would begin to expand. They would all convert into aeriform fluids or gases, and would become part of the atmosphere. These new types of air would mix with those already present, resulting in reciprocal decompositions and new compounds, until the principles composing these different airs or gases should achieve a state of equilibrium determined by their respective affinities for one another.

2.2 *new types of air*: Although "air" most often refers to the gaseous substance that surrounds the earth and which animals breathe, it also has a more general meaning, as here, denoting any gas or vapor.

2.3 But we should not lose sight of the fact that this vaporization would be limited. For as the quantity of elastic fluid increased, the weight of the atmosphere would increase proportionally. And since any pressure would pose an obstacle to vaporization, and since the most evaporable fluids can resist evaporating under great heat so long as that heat is counteracted by a proportionally greater pressure, and, finally, since all liquids, even water itself, can sustain a red heat in Papin's machine, it is clear that the new atmosphere would reach such a degree of heaviness that any water which had not yet evaporated would cease boiling and would remain in a liquid state. As a result, even in the case we are imagining, or in any other case of the same kind, the weight of the atmosphere would be limited and could not surpass a certain boundary. We could carry these reflections much further and examine what would happen to stones, to salts, and to many other substances which can be melted and compose the earth. We could imagine how they would soften, begin melting, and become fluids. But these are digressions, and I hasten to return to the point.

2.4 If the earth were suddenly placed, instead, in some very cold region, just the opposite would occur. The water that makes up our rivers and oceans, and probably most known liquids, would be converted into solid mountains, and into extremely hard rocks. These would be translucent, homogeneous, and white at first, just like rock crystal. But over time, by mixing with substances of different natures, they would become diversely colored opaque stones.

2.3 *the weight of the atmosphere would increase*: The substances which form earth's atmosphere have weight, even though they are in an aeriform state. As more and more materials take on a gaseous condition, so much greater will be the total weight of those gases composing the atmosphere.

any pressure would pose an obstacle to vaporization: Recall Lavoisier's argument that the pressure of the atmosphere is what prevents immediate vaporization of solids and so makes the liquid state possible (1.13).

water ... can sustain a red heat in Papin's machine: Also known as Papin's digester, pictured here, this early pressure cooker was capable of developing pressures so high that water remained liquid even when the apparatus was heated to a red glow.

2.5 Under this supposition the air, or at least some of the aeriform substances composing it, would undoubtedly cease to exist as elastic vapors, due to an insufficient degree of heat. They would therefore return to a liquid state, and we have no idea of the new liquids they would form.

2.6 These two radical suppositions make it clear that (1) *solidity, liquidity,* and *elasticity* are different states of the same matter: three specific modifications through which nearly all substances can pass in succession, and which depend only on the degree of heat to which they are exposed, that is, on the quantity of caloric which penetrates them; that (2) it is very likely that air is naturally a vaporous fluid, or better put, that our atmosphere is a composition of all fluids that can exist in a vaporous state of constant elasticity, at what is, for us, ordinary heat and pressure; and that (3) it would consequently not be impossible to come across otherwise extremely dense substances in our atmosphere, even metals, such as, for example, a metallic substance just a bit more volatile than mercury.

2.7 Among known fluids, some, such as water and alcohol (i.e., spirit of wine), can mix with each other in any proportion. Others, on the contrary, such as mercury, water and oil, can only combine with one another momentarily, and they separate when mixed and arrange themselves according to their specific gravities. The same thing must, or at least can, occur in the atmosphere.

2.6 *it would ... not be impossible to come across otherwise extremely dense substances in our atmosphere*: The density of a substance is measured by the ratio of its weight to the volume it occupies. All the constituents of the atmosphere are in the gaseous state, and must therefore have very low densities in comparison to solids and liquids. But it is possible that some of those gaseous components, if they could be condensed into liquid form, would prove to be metals like mercury, which is more than 13 times as dense as water. Lavoisier will examine the constitution of atmospheric air in the next chapter.

a metallic substance just a bit more volatile than mercury: Mercury exists naturally in the liquid state; but if some metal were only slightly more volatile than mercury, the atmosphere would be likely to contain significant quantities of that metal's vapor.

2.7 *arrange themselves according to their specific gravities*: The specific gravity of a substance is the ratio of its density to the density of water. In an assortment of fluids that do not mix—or even a solid placed in a fluid—the denser material will displace the less dense as it descends. Thus water, with a specific gravity of 1, forms a layer upon the surface of mercury, whose specific gravity is 13.5; Lavoisier observed this at CD in Plate VII, figure 5 (page 22 above). For the same reason olive oil, with a specific gravity of .93, will form a layer upon the surface of water. But such layers would not form if the liquids could mix with one another.

It is possible, even probable, that gases that mix with atmospheric air only with difficulty and tend to separate from it were formed in the very beginning and form constantly since. If these gases are lighter than air, they must collect in higher regions and form layers which float on atmospheric air. The phenomena associated with fiery meteors lead me to believe that there is a layer of flammable fluid like this above the atmosphere, and that the aurora borealis and other fiery atmospheric phenomena take place at the point of contact between these two layers of air. I intend to develop my ideas on this matter in a separate memoir.

2.7, cont. *gases that mix with atmospheric air only with difficulty*: If the particles of gases are as distant from one another as Lavoisier has proposed (1.44), it is hard to understand what sort of "difficulty" could hinder any gas from mixing with any other gas. Nevertheless, such phenomena are observed. Propane gas, widely used for cooking and heating, is denser than atmospheric air under identical conditions. While propane does mix with air, such mixing takes time, especially indoors where there is no wind. To whatever extent the gas has not diffused, it tends to collect in basements, presenting an explosion hazard. Natural gas (largely methane) is less dense than air and so tends to be displaced upwards and diffuse more readily.

aurora borealis: Northern lights. Their underlying causes remain mysterious even today, but they certainly involve some sort of electrical excitation rather than the fiery combustion Lavoisier suggests.