# Letter from Newton to Robert Boyle, dated 28 February 1678/9

**Author:** Isaac Newton

**Source:** MS Add. 9597/2/18/62-65, Cambridge University Library, Cambridge, UK

**Published online:** February 2013

---

<62r>

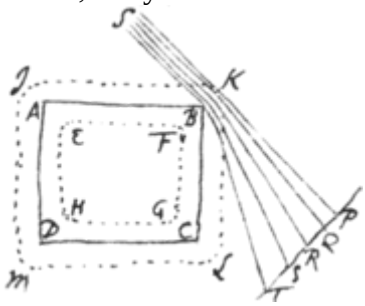
Honoured Sir

I have so long deferred to send you my thoughts about the Physicall qualities we spake of, that did I not esteem my self obliged by promise I think I should be ashamed to send them at all. The truth is my notions about things of this kind are so indigested that I am not well satisfied my self in them, & what I am not satisfied in I can scarce esteem fit to be communicated to others, especially in natural Philosophy where there is no end of fansying. But because I am indebted to you & yesterday met with a friend M$^{r}$ Maulyverer, who told me he was going to London & intended to give you the trouble of a visit, I could not forbear to take the opportunity of conveying this to you by him.

It being only an explication of qualities which you desire of me, I shall set down my apprehensions in the form of suppositions as follows. And first I suppose that there is diffused through all places an æthereal substance capable of contraction & dilatation, strongly elastick, & in a word much like air in all respects, but far more subtile.

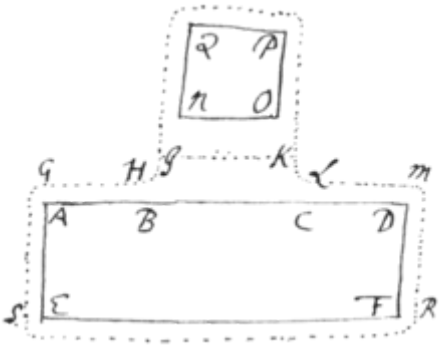
2 I suppose this æther pervades all gross bodies, but yet so as to stand rarer in their pores then in free spaces, & so much the rarer as their pores are less. And this I suppose (with others) to be the cause why light incident on those bodies is refracted towards the perpendicular; why two well polished metalls cohere in a Receiver exhausted of air: why Quicksilver stands sometimes up to the top of a glass pipe though much higher than 30 inches: & one of the main causes why the parts of all bodies cohere. Also the cause of philtration & of the rising of water in small glass pipes above the surface of the stagnating water they are dipt into: for I suspect the æther may stand rarer not only in the insensible pores of bodies, but even in the very sensible cavities of those pipes. And the same principle may cause Menstruums to pervade with violence the pores of the bodies they dissolve, the surrounding æther as well as the Atmosphere pressing them together.

3 I suppose the rarer æther within bodies & the denser without them, not to be terminated in a mathematical superficies but to grow gradually into one another: the external æther beginning to grow rarer, & the internal to grow denser at some little distance from the superficies of the body, & running through all intermediate degrees of density in the intermediate spaces. And this may be the cause why light in Grimaldo's experiment passing by the edge of a knife or other opake body is turned aside & as it were refracted, & by that refraction makes several colours. Let ABCD be a dense body whether opake or transparent, EFGH the outside of the uniform æther which is within it, IKLM the inside of the uniform æther which is without it; & conceive the æther which is between EFGH and IKLM to run through <62v> all intermediate degrees of density between that of the two uniform æthers on either side. This being supposed, the rays of the sun SB, SK, which pass by the edge of this body between B & K, ought in their passage through the unequally dense æther there, to receive a ply from the denser æther which is on that side towards K, & that the more by how much they pass nearer to the body, & thereby to be scattered



through the space PQRST, as by experience they are found to be. Now the space between the limits EFGH & IKLM I shall call the space of the æther's graduated rarity.

4 When two bodies moving towards one another come neare together I suppose the æther between them to grow rarer then before, & the spaces of its graduated rarity to extend further from the superficies of the bodies towards one another, & this by reason that the æther cannot move & play up & down so freely in the strait passage between the bodies as it could before they came so neare together. Thus if the space of the æther's graduated rarity reach from the body ABCDFE only to the distance GHLMRS when no other body is neare it, yet may it reach farther, as to IK, when another body NOPQ approaches: & as the other body approaches more & more I suppose the æther between them will grow rarer & rarer.




These suppositions I have so described as if I thought the spaces of graduated æther had precise limits, as is exprest at IKLM in the first figure & GMRS in the second: for thus I thought I could better express my self. But really I do not think they have such precise limits but rather decay insensibly, & in so decaying extend to a much greater distance then can easily be beleived or need be supposed.

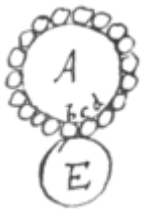
5 Now from the 4th supposition it follows that when two bodies approaching one another, come so neare together as to make the æther between them begin to rarefy, they will begin to have a reluctance from being brought nearer together, & an endeavour to recede from one another: which reluctance & endeavour will encrease as they come nearer together because thereby they cause the interjacent æther to rarefy more & more. But at length, when they come so neare together that the excess of pressure of the external æther which surrounds the bodies, above that of the rarefied æther which is between them, is so great as to overcome the reluctance which the bodies have from being brought together: then will that excess of pressure drive them with violence together & make them adhere strongly to one another, as was said in the second supposition. For instance in the second Figure when the bodies ED & NP are so neare together, that the spaces of the æthers graduated rarity begin to reach to one another & meet in the line IK; the æther between them will have suffered much rarefaction which rarefaction requires much force that is much pressing of the bodies together: & the endeavour which the æther between them has to return to its former natural state of condensation will cause the bodies to have an endeavour of receding from one another. But on the other hand to counterpoise this endeavour there will not yet be any excess of density of the æther which surrounds the bodies above that of the æther which is between them at the line IK. But if the bodies come nearer together so as <63r> to make the æther in the mid-way-line IK grow rarer then the surrounding æther, there will arise from the excess of density of the surrounding æther a compressure of the bodies towards one another: which when by the nearer approach of the bodies it becomes so great as to overcome the afforesaid endeavour the bodies have to recede from one another, they will then go towards one another & adhere together. And on the contrary if any power force them as under to that distance where the endeavour to recede begins to overcome the endeavour to accede, they will again leap from one another. Now hence I conceive it is chiefly that a fly walks on water without wetting her feet, & consequently without touching the water; that two polished pieces of glass are not without pressure brought to contact, no not though the one be plain, the other a little convex; that the particles of dust cannot by pressing be made to cohere, as they would do if they did but fully touch; that the particles of tinging substances & salts dissolved in water do not of their own accord concrete & fall to the bottom, but diffuse themselves all over the liquor, & expand still more if you ad more liquor to them. Also that the particles of vapors exhalations & air do stand at a distance from one another, & endeavour to recede as far from one another as the pressure of the incumbent atmosphere will let them: for I conceive the confused mass of vapors air & exhalations which we call the Atmosphere to be nothing els but the particles of all sorts of bodies of which the earth consists, separated from one another & kept at a distance by the said principle.

From these principles the actions of Menstruums upon bodies may be thus explained. Suppose any tinging body as Cochineel or Logwood be put into water, so soon as the water sinks into its pores & wets on all sides any particle, which adheres to the body only by the principle in second supposition: it takes of or at least much diminishes the efficacy of that principle to hold the particle to the body because it makes the æther on all sides the particle to be of a more uniform density then before. And then the particle being shaken of by any little motion, flotes in the water, & with many such others makes a tincture; which tincture will be of

some lively colour if the particles be all of the same size & density, otherwise of a dirty one. For the colours of all natural bodies whatever seem to depend on nothing but the various sizes & densities of their particles: as I think you have seen described by me more at large in another paper. If the particles be very small (as are those of salts Vitriols & gumms) they are transparent, & as they are supposed bigger & bigger they put on these colours in order black, white, yellow, red; violet, blew, pale green, yellow, orange, red; purple, blew, green, yellow, orange, red &c: as is discerned by the colours which appear at the several thicknesses of very thin plates of transparent bodies. Whence to know the causes of the changes of colours which are often made by the mixtures of several liquors, it is to be considered how the particles of any tincture may have their size or density altered by the infusion of another liquor.

When any metal is put into common water, the water cannot enter into its pores to act on it & dissolve it. Not that water consists of too gross parts for this purpose, but because it is unsociable to metal. For there is a certain secret principle in nature by which liquors are sociable to some things & unsociable to others. Thus water will not mix with oyle but readily with spirit of wine or with salts. It sinks also into wood which Quicksilver will not, but Quicksilvers sinks into metals, which, as I said, water will not. So Aqua fortis dissolves silver not gold; Aqua regis gold & not silver, &c. But a liquor which is of it self unsociable to a body may by the mixture of a convenient mediator be made sociable. So molten Lead which alone will not mix with copper or with Regulus of Mars, by the addition of Tin is made to mix with either. And water by the mediation of saline spirits <63v> will mix with metal. Now when any metal is put in water impregnated with such spirits, as into Aqua fortis, Aqua Regis, spirit of Vitriol or the like, the particles of the spirits as they in floting in the water, strike on the metal, will by their sociableness enter into its pores & gather round its outside particles, & by advantage of the continual tremor the particles of the metal are in, hitch themselves in by degrees between those particles & the body & loosen them from it, & the water entring into the pores together with the saline spirits, the particles of the metal will be thereby still more loosed, so as by that motion the solution puts them into, to be easily shaken of & made to Rote in the water: the saline particles still encompassing the metallick ones as a coat or shell does a kernell, after the manner expressed in the annexed figure. In which figure I have made the particles round, though they may be cubical or of any other shape.

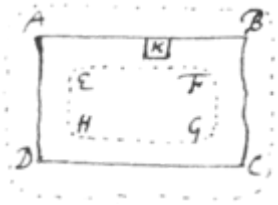
If into a solution of metal thus made, be poured a liquor abounding with particles, to which the former saline particles are more sociable then to the particles of the metal, (suppose with particles of salt of Tartar:) then so soon as they strike on one another in the liquor, the saline particles will adhere to those more firmly then to the metalline ones, & by degrees be wrought of from those to enclose these. Suppose A a metalline particle enclosed with saline ones of spirit of Nitre, & E a particle of salt of Tartar contiguous to two of the particles of spirit of nitre b & c, & suppose the particle E is impelled by any motion towards d so as to roll about the particle c till it touch the particle d: the particle b adhering more firmly to E then to A, will be forced off from A. And by the same means the particle E as it rolls about A will tear of the rest of the saline particles from A, one after another, till it has got them all or almost all about it self. And when the metallic particles are thus divested of the nitrous ones which as a mediator between them & the water held them floting in it: the Alcalizate ones crouding for the room the metallic ones took up before, will press these towards one another & make them come more easily together: so that by the motion they continually have in the water they shall be made to strike on one another, & then by means of the principle in the second supposition they will cohere & grow into clusters, & fall down by their weight to the bottom, which is called precipitation.




In the solution of metals, when a particle is loosing from the body, so soon as it gets to that distance from it where the principle of receding described in the $4^{th}$ & $5^{t}$ suppositions begins to overcome the principle of acceding described in the second supposition: the receding of the particle will be thereby accelerated, so that the particle shall as were with violence leap from the body, & putting the liquor into a brisk agitation, beget & promote that heat we often find to be caused in solutions of Metals. And if any particle happen to leap of thus from the body before it be surrounded with water, or to leap of with that smartness as to get loos from the water: the water by the principle in the $4^{th}$ & $5^{t}$ suppositions, will be kept of from the particle & stand round about it like a spherically hollow arch, not being able to come to a full contact with it any more. And severall of these particles afterwards gathering <64r> into a cluster, so as by the same principle to stand at a distance from one another without any water between them, will compose a buble. Whence I suppose it is that in brisk solutions there usually happens an ebullition.

This is one way of transmuting gross compact substances into aereal ones. Another way is by heat. For as fast as the motion of heat can shake off the particles of water from the surface of it: those particles by the said principle will Rote up & down in the air at a distance both from one another & from the particles of air, & make that substance we call vapor. Thus I suppose it is when the particles of a body are very small (as I suppose those of water are) so that the action of heat alone may be sufficient to shake them asunder. But if the particles be much larger, they then require the greater force of dissolving Menstruums to separate them, unless by any means the particles can be first broken into smaller ones. For the most fixed bodies, even Gold it self, some have said will become volatile only by breaking their parts smaller. Thus may the volatility & fixedness of bodies depend on the different sizes of their parts.

And on the same difference of size may depend the more or less permanency of aereal substances in their state of rarefaction. To understand this let us suppose ABCD to be a large piece of any metal, EFGH the limit of the interior uniform æther, & K a part of the metal at the superficies AB. If this part or particle K be so little that it reaches not to the limit EF, its plain that the æther at its center must be less rare then if the particle were greater, for were it greater, its center would be further from the superficies AB, that is, in a place where the æther (by supposition) is rarer. The less the particle K therefore, the denser the æther at its center, because its center comes nearer to the edge AB where the æther is denser then within the limit EFGH. And if the particle were divided from the body & removed to a distance from it where the æther is still denser, the æther within it must proportionally grow denser. If you consider this you may apprehend how by diminishing the particle, the rarity of the æther within it will be diminished, till between the density of the æther without & the density of the æther within it there be little difference, that is till the cause be almost taken away which should keep this & other such particles at a distance from one another. For that cause, explained in the 4$^{th}$ & 5$^{t}$ suppositions, was the excess of density of the external æther above that of the internal. This may be the reason then why the small particles of vapors easily come together & are reduced back into water unless the heat which keeps them in agitation be so great as to dissipate them as fast as they come together: but the grosser particles of exhalations raised by fermentation keep their aerial form more obstinately, because the æther within them is rarer.




Nor does the size only but the density of the particles also conduce to the permanency of aereal substances. For the excess of density of the æther without such particles above that of the æther within them is still greater. Which has made me sometimes think that the true permanent Air may be of a <64v> metallic original: the particles of no substances being more dense then those of metals. This I think is also favoured by experience for I remember I once read in the Philosophical Transactions how M. Hugens at Paris found that the air made by dissolving salt of Tartar would in two or three days time condense & fall down again, but the air made by dissolving a metal continued without condensing or relenting in the least. If you consider then how by the continual fermentations made in the bowels of the earth there are aereal substances raised out of all kinds of bodies, all which together make the Atmosphere & that of all these the metallic are the most permanent, you will not perhaps think it absurd that the most permanent part of the Atmosphere, which is the true air, should be constituted of these: especially since they are the heaviest of all other & so must subside to the lower parts of the Atmosphere & float upon the surface of the earth, & buoy up the lighter exhalation & vapours to float in greatest plenty above them. Thus I say it ought to be with the metallic exhalations raised in the bowels of the earth by the action of acid menstruums, & thus it is with the true permanent air. For this as in reason it ought to be esteemed the most ponderous part of the Atmosphere because the lowest: so it betrays its ponderosity by making vapors ascend readily in it, by susteining mists & clouds of snow, & by buoying up gross & ponderous smoke. The air also is the most gross unactive part of the Atmosphere affording living things no nourishment if deprived of the more tender exhalations & spirits that flote in it: & what more unactive & remote from nourishment then metallick bodies.

I shal set down one conjecture more which came into my mind now as I was writing this letter. It is about the cause of gravity. For this end I will suppose æther to consist of parts differing from one another in subtilty by indefinite degrees: That in the pores of bodies there is less of the grosser æther in proportion to the finer then in open spaces, & consequently that in the great body of the earth there is much less of the grosser æther in proportion to the finer then in the regions of the air: & that yet the grosser æther in the Air affects the upper regions of the earth & the finer æther in the earth the lower regions of the air, in such a manner that from the top of the air to the surface of the earth & again from the surface of the earth to the center thereof the æther is insensibly finer & finer. Imagin now any body suspended in the air or lying on the earth: & the æther being

by the Hypothesis grosser in the pores which are in the upper parts of the body then in those which are in its lower parts, & that grosser æther being less apt to be lodged in those pores then the finer æther below, it will endeavour to get out & give way to the finer æther below, which cannot be without the bodies descending to make room above for it to go out into.

From this supposed gradual subtilty of the parts of æther some things above might be further illustrated & made more intelligible, but by what has been said you will easily discern whether in these conjectures there be any degree of probability, which is all I aim <65r> at. For my own part I have **{**so**}** little fansy to things of this nature that had not your encouragement moved me to it, I should never I think have thus far set pen to paper about them. What's amiss therefore I hope you will the more easily pardon in

Your most humble Servant & honourer

Is. Newton.

Cambridge Feb 28.
$167\frac{8}{9}$

<65v>

Philosophical Tract from M$^{r}$ Isaac Newton. Cambridge. Feb. 28. 1678/9.

For the Honourable Robert Boyle Esquire