

# Atoms, Entropy, Quanta: Einstein' s Miraculous Argument of 1905

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## Abstract

In the sixth section of his light quantum paper of 1905, Einstein presented the miraculous argument, as I shall call it. Pointing out an analogy with ideal gases and dilute solutions, he showed that the macroscopic, thermodynamic properties of high frequency heat radiation carry a distinctive signature of finitely many, spatially localized, independent components and so inferred that it consists of quanta. I describe how Einstein' s other statistical papers of 1905 had already developed and exploited the idea that the ideal gas law is another macroscopic signature of finitely many, spatially localized, independent components and that these papers in turn drew on his first two, " worthless" papers of 1901 and 1902 on intermolecular forces. However, while the ideal gas law was a secure signature of independence, it was harder to use as an indicator that there are finitely many components and that they are spatially localized. Further, since his analysis of the ideal gas law depended on the assumption that the number of components was fixed, its use was precluded for heat radiation, whose component quanta vary in number in most processes. So Einstein needed and found another, more powerful signature of discreteness applicable to heat radiation and which indicated all these properties. It used one of the few processes, volume fluctuation, in which heat radiation does not alter the number of quanta.

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