

## The stability of matter

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A fundamental paradox of classical physics is why matter, which is held together by Coulomb forces, does not collapse. The resolution is given here in three steps. First, the stability of *atom* is demonstrated, in the framework of nonrelativistic quantum mechanics. Next the Pauli principle, together with some facts about Thomas-Fermi theory, is shown, to account for the stability (i.e., saturation) of *bulk* matter. Thomas-Fermi theory is developed in some detail because, as is also pointed out, it is the asymptotically correct picture of heavy atoms and molecules (in the  $Z \rightarrow \infty$  limit). Finally, a rigorous version of screening is introduced to account for *thermodynamic* stability.

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Although the Schrödinger equation is half a century old, it was only in the last few years that the proof of stability was completed. The aim of this paper is to present the full story in a simple and coherent way, highlighting only the main physical and mathematical ideas.

The sense of profound unease about the problem just before the dawn of quantum mechanics is exemplified by this quotation (Jeans, 1915):

“... there would be a very real difficulty in supposing that the law  $1/r^2$  held down to zero values of  $r$ . For the force between two charges at zero distance would be infinite; we should have charges of opposite sign continually rushing together and, when once together, no force would be adequate to separate them... Thus the matter in the universe would tend to shrink into nothing or to diminish indefinitely in size... We should however probably be wrong in regarding a molecule as a cluster of electrons and positive charges. A more likely suggestion, put forward by Larmor and others is that the molecule may consist, in part at least, of rings of electrons in rapid orbital motion.”