Physics Society - Quantum Basics

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1 The Schrödinger Equation

$$i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$$

It looks intimidating. The formula above is the Schrödinger equation, the central equation of quantum mechanics. However, before we get to that, we first get a grasp of what quantum mechanics exactly is.

I'll assume that you know some of the basics.

The central idea of QM is the **wavefunction**, denoted by Ψ. If we consider the case of an electron, the wavefunction describes the probability amplitude. The value of the wavefunction is dependent on the position and time, so it would be described as a function $\Psi(x, y, z, t)$, dependent on x, y, z and t. For now, we'll talk about a time-independent Schrödinger equation in 1D, so that'll be a wavefunction $\Psi(x)$ that satisfied

$$E\psi = \frac{-\hbar^2}{2m}\frac{d^2\psi}{dx^2} + V\psi$$

.

Let's talk through what each of the terms means. E is the total energy of the system, and V is the total energy of the system. That's how you set up the Schrödinger equation. Squaring the value of the wavefunction gives the **probability** that the particle occupies that particular co-ordinate. Most often, the value of the wavefunction will actually be a **complex number**, hence why there's an i in the full Schrödinger equation seen above.

2 The Heisenberg uncertainty principle

The Heisenberg uncertainty principle is a favourite of popular media, but is often inaccurately portrayed. The actual inequality underpinning it is:

$$\Delta p \Delta x \geq \frac{\hbar}{2}$$

Δp just means the uncertainty in momentum, whereas Δx means uncertainty in position. In essence, this equation states that there is a minimum to the uncertainties in our measurements of position and momentum. Going further, the Heisenberg uncertainty principle actually states that a precise value for position and momentum **does not exist!** This is a tricky concept to get your head around, but is true due to the properties of the wavefunction.

What are the consequences of the Heisenberg uncertainty principle? Well, it means that as you narrow down the position of a particle, its momentum gets higher and higher! Therefore, the concept of **localisation energy** arises, which is the energy that a particle has due to being confined in a region of space. This is the same energy possessed by an electron in an atomic orbital, and the atomic radius is determined by the position at which the electron's total energy (when accounting for electric potential and localisation) is at a minimum.

3 Extra reading

Check out Isaac Science's Quantum mechanics primer book! You can purchase a physical copy of the book for just £1 (not including delivery), and it introduces you to the mathematics behind quantum mechanics. It's very effective at teaching you the basics by working through example problems, instead of just spewing theory. All of the questions are available for free on Isaac Science!

The book called "How to teach quantum mechanics to your dog" by Chad Orzel is incredible for any beginner, and so is "QED - The Strange Theory of Light and Matter" by Richard Feynman, for those who wish to learn about Quantum Electrodynamics, a subset of wider Quantum Physics!

Thank you all for coming!