Digging Heisenberg uncertainty equation!

From the equation:

$$\Delta x \Delta p \approx \frac{h}{4\pi};$$
$$\Delta p = m\Delta v$$

Where Δv is the uncertainty in the measurement of velocity (speed) of an electron. And m is the mass of the electron.

It follows that: $\mathbf{\Delta x \times m\Delta v \approx \frac{h}{4\pi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)}$

Then from (i) above it is clearly understood that the right hand side of the equation, that is $\frac{h}{4\pi}$ is always a constant with a value of approximately 5.275×10^{-35} (taking $h = 6.626 \times 10^{-34}$ and $\pi = 3.14$). *What does this mean?*

The fact that $\frac{h}{4\pi}$ is very small constant implies that **if m could be a mass of large object like a car or stone, the product $\Delta x \times m\Delta v$ would be very large compared to the value of $\frac{h}{4\pi}$ and hence making the Heisenberg uncertainty equation insignificant.** This is the one of the two reasons of why Heisenberg uncertainty principle is not applicable in the daily life where macroscopic objects are commonly involved.

Also the equation may be rearranged to give the following equation;

$$\mathbf{\Delta x \approx \frac{h}{4\pi \times m\Delta v} \ldots\ldots\ldots\ldots (ii)}$$

There are two information that can be extracted from (ii) above;

First information:

The uncertainty in determining position (Δx) of an object of mass, m, varies inversely proportional to the uncertainty in the determination of velocity (Δv) of the object.

- That means if the velocity of the object is determined with more accuracy then its position will determined with less accuracy as suggested in Heisenberg uncertainty principle.

Second information:

The uncertainty in determining position of an object (Δx) varies inversely proportional to the mass of the object (m).

- That means **for macroscopic object whose mass is large, Δx become very small and can be neglected. This is another reason, why Heisenberg uncertainty principle is always ignored in the daily life.**

So putting the two reasons together we may conclude that Heisenberg uncertainty principle is useless in the daily life where macroscopic objects are commonly involved because:

i) For large mass, m, the product $4\pi \times m\Delta v$ becomes very large compared to the value of $\frac{h}{4\pi}$ and therefore making the Heisenberg uncertainity equation inapplicable.

ii) For large mass, m, the uncertainty in the determination of the position of an object would be very small (negligible) even if the equation would be applicable.

Be careful!

Sometimes you may be given the constant $\hbar$(with value of about $1.055 \times 10^{-34} J_s$) instead of the most common Planck constant (with value of about $6.626 \times 10^{-34} J_s$).

- This constant relate to Planck constant as per equation :

$$\hbar = \frac{h}{2\pi}$$

- So from $\Delta x . \Delta P = \frac{h}{4\pi}$;
- The equation may be re-written as

$$\Delta x \Delta p = \frac{1}{2} \times \frac{h}{2\pi}$$

- But $\frac{h}{2\pi} = \hbar$
- Hence $\Delta x \Delta p = \frac{\hbar}{2}$; where $\hbar$ is the **reduced Planck constant**.

Therefore **with given value of $\hbar$ instead of h, use the equation $\Delta x \Delta p = \frac{\hbar}{2}$ instead of $\Delta x \Delta p = \frac{h}{4\pi}$.**

To conclude:

Because of the Heisenberg uncertainty principle, the position of an electron moving with a definite velocity cannot be determined exactly.

- It is only possible to predict the probability of an electron being at a given time and the probability is given by **Schrodinger wave equation** (the concept of Schrodinger wave equation is beyond the scope of this book).

The region in space around the nucleus where there is a maximum probability of finding an electron is called the **atomic orbital**.

WAVE – PARTICLE DUALITY

According to **De Broglie:**

"All material objects are dual in nature, that is; they exhibit both wave and particle characteristics"

Having things like mass is the particle characteristic while having things like wavelength and frequency is the wave characteristics

- So we may combine **Einstein's equation** and **Planck's equation** to get single equation follows:

Consider a photon of light; in **wave model** its energy is given by the following **Planck's equation**:

$$E = hf$$

Where h is Planck's constant

f is the frequency

In the **particle model** the energy is given by the following **Einstein's equation**:

$$E = mc^2$$

Where m is the mass of the photon

c is the velocity.

Equating Plank's and Einstein's equation (Law of conservation of energy)

$$hf = mc^2$$

But $f = \frac{c}{\lambda}$

Then $\frac{hc}{\lambda} = mc^2$

$\frac{h}{\lambda} = mc$ or $\lambda = \frac{h}{mc}$