What is the nature of electrons in atoms?
Light of different colour has a different wavelength

Wavelength:
- short ➔ long

Colour:
- blue ➔ red

Energy:
- high ➔ low
Atomic Spectrum of Hydrogen

- Light emitted from a hydrogen arc lamp is composed of only a few lines:
  - Only light of certain energy is emitted
  - The pattern of lines is unique to hydrogen

- Suggests the process emitting light in the atom is quantised
- The electron in the atom may possess only certain energies

- The real spectrum of H:
Bohr Atom
Atomic emission spectrum is a characteristic of the element

- Bohr model of the atom works well for H but not for other elements
- Quantum mechanics gives a perfect description
Matter ⇔ waves

Diffraction patterns produced by a beam of x-rays and electrons passing through Al foil:

Electromagnetic radiation, such as light, can also be shown to display particle characteristics in some situations.
Quantum Mechanical Model

- Light has a dual nature and the de Broglie equation relates wavelength to momentum
  \[ \lambda = \frac{h}{mv} \]

- Schrödinger Equation
  \[ \hat{H}\psi = E\psi \]

- This can only be solved if various boundary conditions are applied. That is, the waves must be standing waves that are
  - continuous
  - single valued
  - multiples of a whole number of half wavelengths

Quantum Mechanical Model

- There are then discrete solutions that represent the energy of each electron orbital.
- A point in 3-D space may be described by three coordinates; an electron orbital is described by four coordinates.
- The coordinates of the orbital are given by *quantum numbers*. 
Principal Quantum Number, $n$

- $n = 1, 2, 3 ...$
  - Describes the size and extent of the orbital.
  - The larger the value of $n$, orbital is bigger & has higher energy.

$n = 1$  $n = 2$  $n = 3$
Angular Momentum Quantum No, $\ell$

- $\ell = 0, 1, 2\ldots (n - 1)$
- Describes the shape of the orbital
- e.g. if $n = 2$; $\ell = 0$ or 1

$\ell = 0$ "s"
$\ell = 1$ "p"
$\ell = 2$ "d"
$\ell = 3$ "f"
Magnetic Quantum Number, $m_l$

- $m_l = -l, -(l-1) \ldots 0 \ldots (l-1), l$
- Describes the orientation of the orbital
- e.g. if $\ell = 0; m_\ell = 0$ (s orbital)
  - if $\ell = 1; m_\ell = -1, 0, +1$ ($p_x, p_y, p_z$ orbitals)
  - if $\ell = 2; m_\ell = -2, -1, 0, +1, +2$ ($d_{xy}, d_{yz}, d_{xz}, d_{x^2-y^2}, d_z$)
Spin Quantum Number, $m_s$

- $m_s = +\frac{1}{2}, -\frac{1}{2}$
- Describes the spin of the electron.
- Each orbital, uniquely described by $n$, $\ell$ and $m_\ell$, may contain a maximum of two electrons, one spin $+\frac{1}{2}$, the other spin $-\frac{1}{2}$

**Why is this important?**

- Relates to a thorough understanding of the periodic table
  - Size of atom/ion related to metal toxicity
- Relates to type of bonds ($\sigma$ or $\pi$) formed in compounds
  - Shape – essential for design of selective drugs
**Question:**

Complete the table with possible values

<table>
<thead>
<tr>
<th>Shell, $n$</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-shell, $\ell$</td>
<td>0</td>
<td>0, 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>$s$</td>
<td>$s, p$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum no. of electrons in sub-shell</td>
<td>2, 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total electrons</td>
<td>2</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>