Thurs: HW 14 due by 5pm

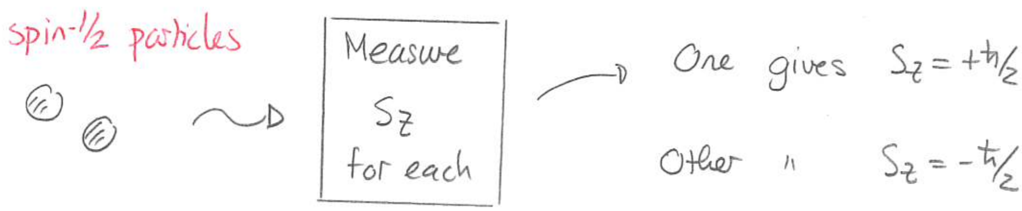
Fri: Read.

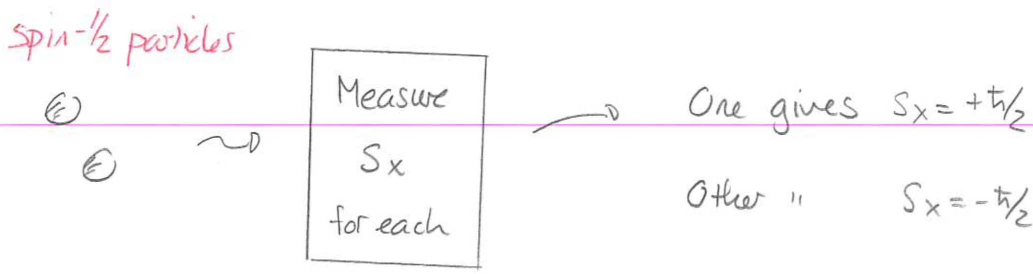
Multiple Particles

When a system contains multiple particles we have seen that the wavefunctions that describe these are either

1) symmetrical ~ wavefunction is same under interchange of particles
2) antisymmetrical ~ wavefunction changes by a factor of -1 under interchange of particles.

These ideas were developed for position wavefunctions but they apply equally well to other quantities such as spin that are not related to spatial variables. It turns out that for two identical spin-½ particles the state must be antisymmetrical. In terms of measurements this means





If the same component of spin is measured for each particle the outcomes will always be opposite. In this sense their states are different.

Any particle falls into one of two categories.

1) Bosons: two identical indistinguishable particles can be in the same state

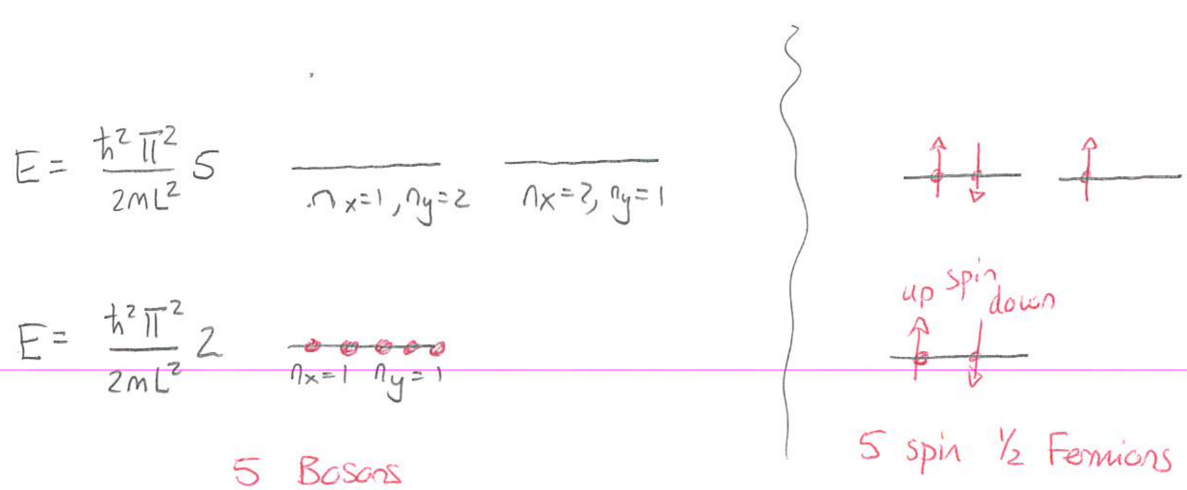
2) Fermions: two indistinguishable particles must be in different states.

Electrons are examples of Fermions.

If we know the possible states for a system then, provided the particles are non-interacting, we can fill up the energy levels accordingly. For example consider a two-dimensional square well. The states are labeled with $n_x, n_y = 1, 2, 3, \ldots$ and energies

$$E = \frac{\hbar^2 \pi^2}{2mL^2}\left(n_x^2 + n_y^2\right)$$

The lowest few energies could be occupied by Bosons or Fermions as illustrated.



Multielectron Atoms

Since an electron is a spin-½ particle, it is a Fermion. Thus the electrons in any single multielectron atom will abide by:

> Two electrons cannot occupy the same state in an atom.

The states of a multielectron atom will be labeled in the same way as for a hydrogen atom with the same rules about n, l, m_l. We have

$n = 1, 2, 3, \ldots$ $\qquad$ $E_n =$ formula (unknown) different to that for Hydrogen

$l = 0, 1, 2, \ldots, n-1$

$m_l = -l, -l+1, \ldots, l-1, l$

$m_s = +\frac{1}{2}, -\frac{1}{2}$

Thus every electron state can be represented via a list (n, l, m_l, m_s) and the lists for two electrons cannot be identical. So

$(2,1,1,\frac{1}{2})$ same as $(2,1,1,\frac{1}{2})$

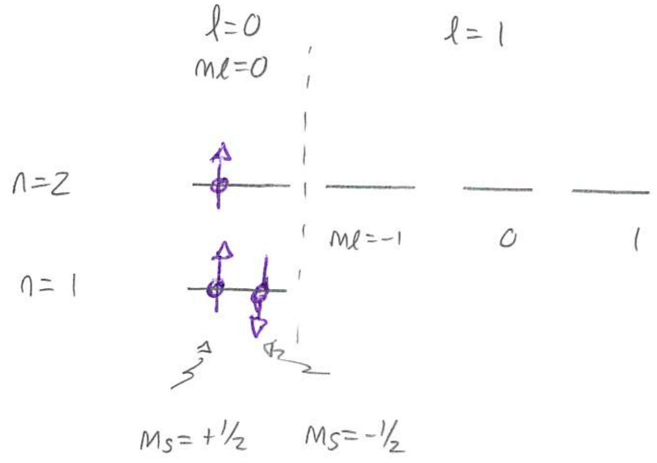
different to $(2,1,1,-\frac{1}{2})$

$(2,1,-1,\frac{1}{2})$

$(3,1,1,\frac{1}{2})$

etc...

It's convenient to display these on an energy level diagram. For example, consider Lithium (3 electrons). In its lowest energy state



It would appear that the $n=2, l=0$ or $n=2, l=1$ states could be occupied with equal probability. But various inter-electron interactions reduce the $l=0$ energies relative to $l=1$

Periodic Table

The periodic table displays all the atomic elements. They are arranged based on how they combine to form chemical compounds. For example:

$NaCl$ $\qquad$ $MgCl_2$

KCl $\qquad$ $CaCl_2$

The basic structure of the periodic table was known in the 1860s but the reasons for its structure were not known until quantum theory had been developed

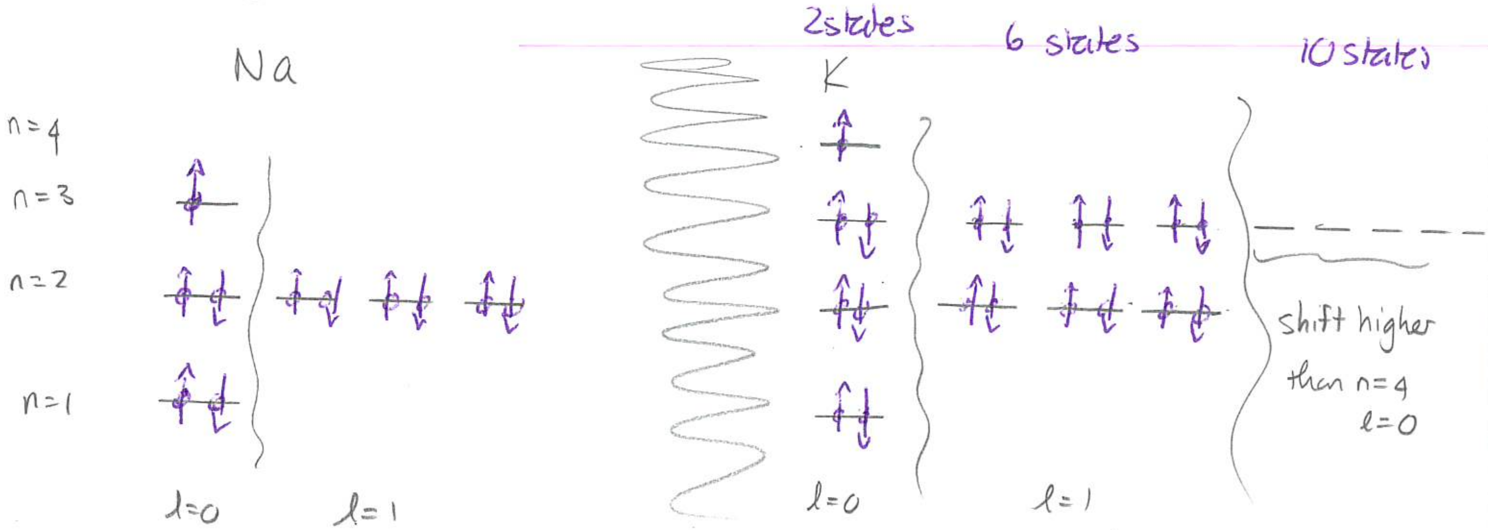
Demo: Periodic Table

Consider the other elements in Group 1

Na ⇝ 11 electrons

K ⇝ 19 electrons

The energy states are filled as



⇒ Both have one electron in an $l=0$ state and all other ranges filled.

↳ react in similar ways

The next element like this will have to fill

$n=4$ $l=0$ ⇝ 1 more electron
$n=3$ $l=2$ ⇝ 10 more electrons
$n=4$ $l=1$ ⇝ 6 more electrons
$n=5$ $l=0$ ⇝ 1 more electron

} 18 more electrons

⇓

37 electrons in total

⇒ Rubidium

Quiz 1