<@BrianQ> I was talking with a physical chemistry professor last week, and found out something interesting

[21:14] <@BrianQ> Physical chemists are pretty familiar with quantum mechanics... but apparently, nowadays, they only learn its details in grad school

[21:15] <doos> grad school is at which level?

[21:15] <@BrianQ> New rules of chemistry accreditation really put the squeeze on how much quantum mechanics can be taught in an undergraduate physical chemistry class.

[21:16] <doos> you mean as in copyright?

[21:16] <@BrianQ> No, as in, you have to cover so many topics that you don't have enough time to teach in detail

[21:16] <doos> ah

————————————————01[21:16] <@Spauwe> sounds familiar

[21:16] <@BrianQ> I took physical chemistry as an undergraduate... a two-semester course... and we covered

[21:17] <@BrianQ> about as much quantum mechanics as I did in my "modern physics" course.

[21:17] <Frank___> so no quantum till after graduation

[21:17] <@BrianQ> but we covered other topics too... primarily thermodynamics, for one.

[21:18] <@BrianQ> Nowadays, they definitely don't have time to cover as much as what we do in "modern physics" and so...

[21:18] <@BrianQ> what they do learn is very, very similar to what I have been teaching you guys!

[21:19] <Keirkof> some piccies contain local geology, but most do not ^^

[21:19] <@BrianQ> In fact, I listened in to their final exam, and the questions were pretty much the sort I could ask you guys.

[21:20] <@BrianQ> For example, "which quantum mechanical system leads to equally-spaced energy states?"

[21:20] <@BrianQ> any takes?

[21:20] <@BrianQ> any takers?

————————————————01[21:20] <@Spauwe> none here

[21:20] <Keirkof> wooh, not me i'm afraid

[21:20] <doos> we covered that last time

[21:20] <doos> didn't we?

[21:20] <@BrianQ> indeed, we did.

————————————01[21:20] <@Spauwe> missed that bit

[21:21] <doos> (1,1,1)

[21:21] <@BrianQ> nope...

[21:21] <doos> the sphere one?

[21:21] <@BrianQ> a name, like "particle in a box"... except that isn't the correct answer

[21:21] <Frank___> single line particle in a box?

[21:21] <@BrianQ> not the sphere one either :)

[21:21] <doos> heh

[21:22] <@BrianQ> not the single dimension particle in the box either

[21:22] <Frank___> harmonic oscillator

[21:22] <doos> the square one?

[21:22] <@BrianQ> yes, the harmonic oscillator!

[21:22] <doos> bugger

[21:22] <@BrianQ> point to Frank ;)

[21:22] <Frank___> later doos

[21:22] <Frank___> nanananana

————————————01[21:22] <@Spauwe> :)

[21:23] <doos> oh I'll get you back

————————————01[21:23] <@Spauwe> you'll wake up with a sticky face next week

[21:23] <@BrianQ> now, as to the homework problem... how many degeneracies at 14E0?

[21:23] <doos> 5

[21:23] <Frank___> 6

————————————01[21:23] <@Spauwe> gheheh

————————————01[21:23] <@Spauwe> 7

————————————01[21:23] <@Spauwe> hahaha

[21:23] <@BrianQ> oo, Frank gets it again!

[21:23] <doos> (3,1,1,1,1,1)?

[21:24] <Frank___> feeling smug

[21:24] <@BrianQ> no, only three quantum numbers for three dimensions

[21:24] <Frank___> 123   132   213   231   312   321

[21:24] <@BrianQ> Beat me to what I was going to ask, Frank... really awake today!

[21:24] <doos> oh yes .. sorry didn't reread the last log

[21:25] <@BrianQ> now, to help Keirkof and Spauwe a bit, and to review a bit...

——————————————01[21:25] <@Spauwe> thanx... ;)

[21:26] <@BrianQ> We are looking at solvable problems in quantum mechanics... which are solved by what are called energy eigenstates

——————————————01[21:26] <@Spauwe> just kicked out the president of the local court and the minister of foreign affairs to be here

[21:26] <@BrianQ> or stationary states, or about a hundred other synonyms.

——————————————01[21:26] <@Spauwe> started to feel lost

——————————————02[21:27] * _Frank_ (i=Frank@84.4.57.129) Quit (No route to host)

——————————————01[21:27] <@Spauwe> eigenstates, works, sounds like dutch

[21:27] <@BrianQ> german, I think

[21:27] <doos> yes german

——————————————01[21:27] <@Spauwe> scaringly similar

[21:27] <doos> but same word in durtch

[21:27] <doos> -r

[21:28] <@BrianQ> now these stationary states are distinguished by a set of quantum numbers

[21:28] <@BrianQ> in a one-dimensional problem, there is one quantum number that distinguishes each state.

[21:29] <Keirkof> they're called after a chap called 'Eigen', nothing to do with the dutch word meaning 'own'

[21:29] <@BrianQ> in a three-dimensional problem, there are three quantum numbers to distinguish each state

[21:29] <@BrianQ> no... it does mean "own".

[21:29] <@BrianQ> The state's own energy, so to speak

01[21:29] <@Spauwe> it's own state

01[21:29] <@Spauwe> I can see that...

[21:29] <Keirkof> noooooo

[21:30] <doos> ssst

[21:30] <Keirkof> that's just coincidence, believe me ^^

01[21:30] * @Spauwe slaps Keirkof around a bit with a large trout

01[21:30] <@Spauwe> ghehe

[21:30] <Keirkof> okay, okay ^^

[21:30] <@BrianQ> for example, we discussed what is called the one-dimensional "particle in a box"

[21:31] <@BrianQ> the eigenstates might be represented by a w and depend on position x and time t...

[21:31] <@BrianQ> and be indexed by the quantum number n

[21:31] <@BrianQ> W_n(x,t)

[21:32] <@BrianQ> so the n is a subscript to identify a specific function...

[21:32] <@BrianQ> The reason these are called stationary state, is that the energy associated with each state doesn't change.

[21:33] <@BrianQ> They have their own energy, and it doesn't change... energy eigenstate w_n(x,t)

[21:33] <@BrianQ> Now the energy associated with each state (called the energy eigenvalue) usually is some collection of constants...

[21:34] <@BrianQ> and some dependence on the quantum numbers.

[21:34] <@BrianQ> We have been using the symbol E0 to represent the collection of constants.

[21:34] <@BrianQ> This collection of constants is different for different problems, but what is of interest to us...

[21:35] <@BrianQ> is how the energy depends on quantum numbers.

[21:35] <@BrianQ> The particle in a box problem, each stationary state w_n has energy E_n = n^2*E0

01[21:36] <@Spauwe> why the 2?

[21:36] <@BrianQ> The quantum numbers for particle in a box are positive integers... n = 1,2,3...

[21:36] <@BrianQ> that is n-squared... n*n = n^2

[21:36] <Frank___> it means squared when used with the ^

————————————————01[21:36] <@Spauwe> ok

[21:37] <@BrianQ> So... what is the energy of the n = 1 state?

————————————————01[21:37] <@Spauwe> 1

[21:37] <doos> 1EO

[21:37] <@BrianQ> yes, Doos is a bit more proper.

————————————————01[21:37] <@Spauwe> yep get that...

[21:37] <@BrianQ> and what is the energy of the n=2 state?

————————————————01[21:37] <@Spauwe> 4eo

[21:37] <@BrianQ> yep, and then the n=3 state?

————————————————01[21:38] <@Spauwe> 9eo

[21:38] <@BrianQ> yep..

[21:38] <@BrianQ> now we learned to draw what is referred to as "energy-level diagrams"... do you have paper and pencil?

————————————————01[21:38] <@Spauwe> yesh

[21:38] <doos> can I borrow a pencil?

[21:38] <@BrianQ> Too bad the blackboard isn't in place, Doos was a wizard at drawing these

[21:38] <Frank___> shame we lost the blackboard

[21:39] <doos> want me to fire up the blackboard?

[21:39] <Frank___> yes please

[21:39] <doos> holdon .. see if it still works

[21:40] <@BrianQ> Ok, while Doos is checking the blackboard, I'll fill you in on another one-dimensional problem

[21:40] <@BrianQ> called the harmonic oscillator...

[21:41] <@BrianQ> This is a problem where the particle feels a force always pulling it back to some equilibrium position...

[21:41] <Frank___> I have a screen shot of the blackboard with all the values shown

[21:41] <@BrianQ> like a pendulum swinging..

[21:41] <Frank___> including the homework values

[21:41] <doos> http://yey.be/chat/drawboard/blackboard.html

[21:42] <Frank___> but i dont think I can copy and paste it back onto the blackboard

[21:42] <doos> let me know if it's working

[21:42] <@BrianQ> yep, I just got rid of that light grey!

[21:42] <doos> okay some changed the colors so must be working

[21:42] <doos> ok

[21:42] <Frank___> loading

[21:43] <@BrianQ> Tim, Keirkof, can you guys load the blackboard?

————————————————01[21:43] <@Spauwe> yep works

[21:43] <@BrianQ> Doos can you make a vertical line for the energy scale, marked off in steps of E0?

[21:43] <doos> ok

[21:44] <Frank___> Doos can I get a copy of last weeks chrt and paste it on in any way

[21:46] <Frank___> shall I start typing in values?

[21:46] <doos> sure

[21:46] <doos> enough lines BrianQ?

[21:48] <doos> heh

[21:48] <@BrianQ> looks good!

[21:49] <@BrianQ> now we can locate the energies of the particle in the box... a horizontal line at E0 identified with n=1

[21:49] <Frank___> shall we fill in the values for n=1 n=2 n=3?

[21:49] <@BrianQ> another horizontal line at 4E0 identified with n=2... yes Frank

[21:50] <@BrianQ> another at 9E0 identified with n=3, another at 16E0 identified with n=4

[21:50] <@BrianQ> so Tim, do you see how the energy level diagram is created?

————————————————01[21:51] <@Spauwe> if the horizontal line represents time and place : yes

[21:51] <@BrianQ> No, the horizontal line just marks the energy of the stationary state.

[21:52] <@BrianQ> for example, n=3 stationary state has energy (looking at vertical scale) of 9E0

[21:52] <@BrianQ> great job Doos.

————————————————01[21:52] <@Spauwe> yep got it

[21:52] <Frank___> also note in this model the spaces between the energy states increases

————————————————01[21:52] <@Spauwe> exponentially

[21:53] <@BrianQ> Now Frank brings up the point we want to observe in these diagrams...

[21:53] <doos> was Frank___ I think

[21:53] <Frank___> joint effort doos

[21:53] <@BrianQ> As n increases, the energy spacing between adjacent n is increasing (geometrically, not exponentially)

————————————————01[21:54] <@Spauwe> okay...

[21:54] <@BrianQ> heh

[21:54] <@BrianQ> Now that other problem, the harmonic oscillator, has states designated by a single quantum number n

[21:55] <@BrianQ> W_n and their energies are given by E_n = E0(n+1/2)

[21:55] <@BrianQ> and the quantum numbers are non-negative integers... n = 0,1,2,3...

[21:55] <@BrianQ> So what is the lowest quantum number, and what is the energy of the state with that quantum number?

[21:56] <Frank___> n=0 at 1/2EO

[21:56] <@BrianQ> We don't need to draw the energy level diagram on the board, hopefully we can do this at home, now that we see how it is supposed to go.

[21:56] <@BrianQ> yes Frank

[21:56] <@BrianQ> and the next state, and its energy?

————————————————01[21:57] <@Spauwe> n=1 at 1.5 eo

[21:57] <@BrianQ> yes, and the next state?

[21:57] <@BrianQ> and its energy?

————————————————01[21:58] <@Spauwe> n+2 at 3eo

————————————————01[21:58] <@Spauwe> n+2

[21:58] <Frank___> n=2 at 21/2EO

————————————————01[21:58] <@Spauwe> arg

——————————————01[21:58] <@Spauwe>]yep

[21:58] <@BrianQ> yes Frank ;)

[21:58] <doos> at 10.5?

[21:58] <doos> 21 / 2

[21:58] <@BrianQ> heh, at 2.5 E0

[21:58] <Frank___> n=10 at 10.5

——————————————01[21:58] <@Spauwe> 21/2?

[21:58] <doos> heh

[21:59] <@BrianQ> 2 and 1/2 = 2.5

[21:59] <Frank___> sorry feeling fractious

[21:59] <@BrianQ> and yes Frank

[21:59] <@BrianQ> fractions are fine

[21:59] <@BrianQ> so Tim, try drawing an energy level diagram with those... n = 0, 1, 2, 3...

[22:00] <@BrianQ> and what is happening to the energy spacing between adjacent n, as n increases?

[22:00] <Frank___> remains constant

——————————————01[22:01] <@Spauwe> yeah...

[22:01] <@BrianQ> yes... same spacing ...

[22:01] <@BrianQ> a notable difference from the particle in the box.

[22:01] <@BrianQ> Next, we moved onto a three-dimensional problem... particle in a square box...

[22:02] <@BrianQ> you need three quantum numbers nx, ny, and nz... nx = 1,2.. ny = 1,2.. nz = 1,2,3..

[22:02] <@BrianQ> stationary state is indexed by three quantum numbers... w_nx,ny,nz

[22:03] <@BrianQ> sometimes it is easier for us to use the notation (nx,ny,nz)

[22:04] <@BrianQ> Then the energy of each of these stationary states is given by E_nx,ny,nz = E0*(nx^2+ny^2+nz^2)

——————————————01[22:04] <@Spauwe> ghehe

——————————————01[22:04] <@Spauwe> I don't like formulas

——————————————01[22:04] <@Spauwe> ;)

[22:05] <@BrianQ> In each of these models, there is always some state that has the lowest energy... this is called the "ground state"

————————————————————01[22:05] <@Spauwe> but this one makes sense

————————————————————01[22:05] <@Spauwe> yes familiar with that term

[22:05] <Frank___> Doos first one should be at 3EO I think

[22:05] <@BrianQ> The ground state of the simple harmonic oscillator was n = 0 with energy 1/2*E0

[22:06] <doos> oh yes damned

[22:06] <@BrianQ> Yes, for the 3-D square particle in the box, the ground state is (1,1,1) with energy 3E0

————————————————————01[22:06] <@Spauwe> ok, I actually see that

————————————————————01[22:06] <@Spauwe> surprisingly

[22:07] <Frank___> next at 6

[22:07] <@BrianQ> The next energy is at 6E0 with three states having that energy, (1,1,2) and (1,2,1) and (2,1,1)

[22:07] <@BrianQ> These states are said to be "degenerate"... meaning they have the same energy

[22:08] <@BrianQ> Three degenerate states at energy 6Eo

[22:08] <Frank___> lol ok you draw I'll type

[22:08] <doos> ok

[22:08] <@BrianQ> Now as we explored this problem, Tim, we found that energies show up kind of randomly..

[22:09] <@BrianQ> higgly piggly, and that the number of degenerate states at each allowed energy was also kind of random

[22:09] <Frank___> next lines at 9

————————————————————01[22:09] <@Spauwe> yes, that was my question

————————————————————01[22:10] <@Spauwe> with 2.2.1 En = 9 isnt it?

[22:10] <@BrianQ> The homework problem we were talking about was to identify an energy where we left off last time...

[22:10] <@BrianQ> and how many degenerate states... it turns out at 14E0 there are six degenerate states...

[22:11] <@BrianQ> But at the allowed energy just below that, there is only one state that can have that energy.

[22:11] <Frank___> the one at EO 12 is a single state

[22:11] <@BrianQ> indeed!

[22:11] <Frank___> and 6 at 14

————————————————01[22:11] <@Spauwe> ok... slowly but surely...

[22:11] <doos> heh

[22:12] <@BrianQ> So it is kind of wacky... but there is a reason for this... a cube is not a very symmetric shape, and so the energies get kind of randomized by the imperfect symmetry.

[22:12] <@BrianQ> And... the energy spacing is kind of randomized by the imperfect symmetry.

————————————————01[22:13] <@Spauwe> a sphere would be better

————————————————01[22:13] <@Spauwe> ?

[22:13] <@BrianQ> Now let's look at a 3-D problem with better symmetry... exactly, a sphere

[22:13] <@BrianQ> the spherical particle in a box.

[22:13] <@BrianQ> We still need three quantum numbers, this time they are...

[22:14] <@BrianQ> n (called principle quantum number), l (called angular momentum quantum number), and m (called magnetic quantum number)

[22:14] <@BrianQ> the names are for historical reasons, and don't really affect our discussion much

[22:15] <@BrianQ> n can take positive integer values n = 1,2,3,...

[22:15] <doos> (sidebar .. I think at 6EO it should be (1,1,2) etc

[22:15] <@BrianQ> l can take non-negative integer values l = 0,1,2,3...

[22:15] <@BrianQ> yes, Doos

[22:16] <@BrianQ> and m is weird... it varies from -l to l in integer steps.

[22:16] <@BrianQ> So, for example, maybe I have a state n = 2, l = 2... then there are five possible m values...

[22:17] <doos> -2, -1, 0 1, 2

[22:17] <@BrianQ> m = -2, -1, 0, 1, 2

[22:17] <@BrianQ> yep

[22:17] <Frank___> yes your right

[22:17] <doos> told ya I'd get you back

————————————————01[22:17] <@Spauwe> ghehe

[22:17] <@BrianQ> Now this is a higher symmetry problem, and as a result, the energy of each state depends only on two quantum numbers, not three.

[22:18] <Frank___> sowwy

[22:18] <@BrianQ> for a given state (n,l,m) the energy is E_n,l ... so all different m states will be degenerate

[22:19] <@BrianQ> so, for example if n=2 and l=2, how many states will have the energy E_2,2?

————————————————01[22:19] <@Spauwe> 3?

————————————————01[22:20] <@Spauwe> guessing

————————————————01[22:20] <@Spauwe> don't see it just yet

[22:20] <@BrianQ> five... m = -2,-1,0,1,2

————————————————01[22:21] <@Spauwe> so you would write that down as 2.2.5?

[22:22] <Frank___> cant m=3 or -3 in these cases?

[22:22] <doos> when l = 3

[22:22] <@BrianQ> no.. m value ranges between -l and +l in integer steps.

[22:22] <Frank___> ah ok sorry I read that as a 1

[22:22] <@BrianQ> yes, if l = 3, then you could have m = -3,-2,-1,0,1,2,3

[22:23] <@BrianQ> Yep, maybe I should use L to avoid confusion, and M

[22:23] <@BrianQ> now... the form of the energy eigenvalues

[22:23] <@BrianQ> for the same value n, a higher L value lies at a higher energy...

[22:24] <@BrianQ> The math is a bit messy, but we can give an exact result for L=0, and approximate result for L=1, and a rough guess result for higher Ls

[22:25] <@BrianQ> If L=0, then E_n,0 = n^2*E0

[22:25] <doos> = 0?

[22:26] <@BrianQ> If L=1, then approximately E_n,1 = (n+1/2)^2*E0

[22:26] <doos> = 2.25

[22:26] <@BrianQ> remember, the energy depends on two quantum numbers now, E_n,l

————————————————01[22:26] <@Spauwe> Does L=0 ever happen in nature?

[22:27] <doos> groundstate I think

[22:27] <@BrianQ> Yes, it is the lowest energy for a given n

[22:27] <@BrianQ> ground state will be n=0, l=0

[22:27] <@BrianQ> With energy?

[22:27] <doos> 0EO

[22:27] <@BrianQ> oops...

————————————————01[22:27] <@Spauwe> yeppesh

————————————————01[22:27] <@Spauwe> no?

[22:27] <@BrianQ> I mean n=1, L=0

[22:27] <@BrianQ> n starts at 1, not 0

[22:27] <doos> .025EO

[22:27] <@BrianQ> L starts at zero

————————————————01[22:28] <@Spauwe> ok

[22:28] <doos> 0.25

[22:28] <Frank___> n can't = zero it can only be a positive integer

[22:28] <@BrianQ> no.. E0

————————————————01[22:28] <@Spauwe> you are switched on tonoght aren't you ?

[22:29] <@BrianQ> he is indeed

[22:29] <@BrianQ> ok, now what is the next higher-energy state and what is its energy?

[22:29] <Frank___> I'm taking really scrappy notes so I dont have to keep scroling up

[22:30] <doos> if n= 1, then the formula is 1.5^2EO .. right?

[22:30] <@BrianQ> Is it n=2 l=0 or is it n=1 l=1?

[22:30] <Frank___> n=1 l=1

————————————————01[22:30] <@Spauwe> n=1, L=1 m can be -1 to =1

————————————————01[22:30] <@Spauwe> +1

————————————————01[22:30] <@Spauwe> i mean

[22:30] <@BrianQ> no, you have to choose both n and L, different energy formulas for different Ls

[22:31] <@BrianQ> yes Spauwe

[22:31] <@BrianQ> Yes Frank, the next energy is n=1, L=1, with energy...?

[22:32] <doos> gawd, I'm really having a blonde day

——————————————01[22:32] <@Spauwe> you are blond...

[22:32] <doos> true

[22:32] <Frank___> 2.25

[22:32] <@BrianQ> 2.25E0

[22:32] <Frank___> EO

[22:32] <@BrianQ> heh

[22:33] <@BrianQ> anyways, one can map out these spherical particle in a box energy states as well, and we'd see some things like...

[22:33] <@BrianQ> As n increases, energy spacing between n's increase.

[22:34] <@BrianQ> As l increases, energy spacing between l's (of the same n) actually decrease

[22:34] <doos> so you get a staircase pattern?

[22:34] <Frank___> Brian what happens when L reaches higher numbers...do we have to calculate for all possible values of M

[22:35] <@BrianQ> energy doesn't depend on M

——————————————01[22:35] <@Spauwe> that strikes me as odd...

[22:35] <Frank___> so m is never part of the maths?

[22:35] <@BrianQ> just the number of states that are located at that energy does depend on M

——————————————01[22:35] <@Spauwe> magnetic states don't influence energy?

[22:35] <@BrianQ> M is not a part of this energy, no

[22:36] <Frank___> ah ok I see it now

[22:36] <@BrianQ> no... and this is because of the higher symmetry...

[22:36] <@BrianQ> now.. if we put this thing in a magnetic field... that would reduce symmetry, and the Ms would become important

[22:36] <Frank___> m merely dictates the number of possible states there may be but doesn't affect the energy (EO) value

——————————————01[22:36] <@Spauwe> righto...

[22:36] <@BrianQ> which is why they got the name magnetic quantum number

[22:37] <@BrianQ> yes Frank, exactly

[22:37] <@BrianQ> This is a high symmetry problem which means that the M quantum number doesn't come into play.

[22:38] <@BrianQ> Now let's look at another high symmetry problem, the highest symmetry...

[22:38] <@BrianQ> it has, what one might refer to as, a hidden symmetry.

[22:38] <@BrianQ> This is the problem of the hydrogen atom.

————————————————01[22:38] <@Spauwe> ow yippee, exeptions to the rule...

[22:38] <@BrianQ> A single electron feels an electric attraction to the nucleus (proton)

[22:39] <@BrianQ> This electric force (except for some constants) looks mathematically like the gravitational force.

[22:40] <@BrianQ> And both these forces are spherical (good) and have an additional symmetry (better)

[22:40] <@BrianQ> now, once again, with spherical symmetry, we use the same notation for the quantum numbers...

[22:40] <@BrianQ> n (principle) L (angular momentum) and M (magnetic)

[22:41] <@BrianQ> but the range for L changes slightly...

[22:41] <@BrianQ> n takes on positive integer values n = 1,2,3...

[22:42] <@BrianQ> now, L can take on integer values from zero to n-1

————————————————01[22:42] <@Spauwe> as in moving eclips like?

[22:42] <@BrianQ> are you asking about the hidden symmetry?

————————————————01[22:42] <@Spauwe> no the changing L

[22:43] <@BrianQ> oh.. the change in its range of values arises from the hidden symmetry.

[22:43] <@BrianQ> For example, if n = 2, then L can be values 0 or 1 only

————————————————01[22:43] <@Spauwe> ok continue I may catch up eventually

[22:43] <@BrianQ> if n = 4, the L can be values 0,1,2,3

————————————————02[22:44] * Barbra (n=Barbra@c-67-161-65-50.hsd1.ca.comcast.net) Quit (Read error: 110 (Connection timed out))

[22:44] <Frank___> there goes the log

[22:44] <@BrianQ> M works the same way... takes on values from -L to L in integer steps...

————————————————01[22:44] <@Spauwe> keirkof is stil here...

[22:44] <@BrianQ> oops so true.

[22:44] <@BrianQ> DragonStek is too.

[22:44] <DragonStek> hi

[22:44] <@BrianQ> heh

[22:44] <doos> hi

————————————————01[22:44] <@Spauwe> hey you quiet one

[22:44] <DragonStek> been here just being quite

————————————————03[22:45] * Barbra (n=BarbraBo@c-67-161-65-50.hsd1.ca.comcast.net) has joined #gemology

[22:45] <@BrianQ> ok... now there is how the quantum numbers can change....

[22:45] <@BrianQ> Well, now Barbra didn't miss much.

————————————————01[22:46] <@Spauwe> ghehe

————————————————01[22:46] <@Spauwe> must have autoconnect on

[22:46] <@BrianQ> Let us say, for example.... how many states can have n = 4?

[22:46] <@BrianQ> um... let's start more simply...

[22:46] <doos> for hydrogen?

[22:46] <@BrianQ> how many can have n = 1

[22:46] <@BrianQ> yes, for hydrogen

[22:46] <Frank___> do we use the spherical formula?

[22:47] <doos> 2

[22:47] <@BrianQ> The sets of allowed quantum numbers L and M for n = 1 are...

[22:47] <@BrianQ> L=0, M =0 only one state...

[22:47] <Frank___> 0

[22:48] <doos> oh righ 0 to n-1

[22:48] <@BrianQ> L must lie between 0 and n-1, M must lie between -L and L

[22:48] <@BrianQ> so only one state for n = 1 (1,0,0)

[22:48] <@BrianQ> what about n=2?

[22:49] <Frank___> L can be 0 or 1

[22:49] <Frank___> M can be -1, 0 or 1

[22:49] <doos> and m is has 5

[22:49] <@BrianQ> (2,1,-1) (2,1,0) (2,1,-1) and (2,0,0) four possible states

[22:50] <@BrianQ> oops, that third one should be (2,1,1)

[22:50] <@BrianQ> n = 1 can have one state

[22:50] <@BrianQ> n = 2 can have four states.

[22:50] <@BrianQ> how about n = 3?

[22:50] <doos> 9

[22:51] <@BrianQ> good guess, can you list 'em?

[22:51] <doos> (just following a pattern)

————————————————01[22:51] <@Spauwe> ghehe

[22:51] <doos> (3,0,-2) ...

[22:51] <Frank___> 3,0,-2   3,1,-2

[22:52] <Frank___> 3,2,-2   3,0,-1   3,1,-1   3,2,-1

[22:53] <Frank___> 3,0,0   3,1,0   3,2,0

[22:53] <@BrianQ> (3,2,-2) (3,2,-1) (3,2,0) (3,2,1) (3,2,2) (3,1,-1) (3,1,0) (3,1,1) (3,0,0)

[22:53] <@BrianQ> do they match?

[22:53] <@BrianQ> We'll assume so ;)

[22:53] <doos> almost

[22:53] <Frank___> 3,0,1 3.1.1   3.2.1

[22:53] <Frank___> more than 9 though arent there

[22:54] <@BrianQ> no... for n=3 there are 9...

[22:54] <Frank___> 3,0,2   3,1,2   3,2,2

[22:54] <@BrianQ> for n =4 it happens that there are 16

[22:54] <@BrianQ> strangely enough ;)

————————————————01[22:54] <@Spauwe> n^2xEO

————————————————01[22:54] <@Spauwe> back t where we started

[22:54] <@BrianQ> no... that is an energy you are trying to write and that is not the correct form...

————————————————01[22:55] <@Spauwe> ow...

[22:55] <@BrianQ> what we are doing is counting the number of states with the same n...

————————————————01[22:55] <@Spauwe> and it happens to be n^2 as well?

[22:55] <@BrianQ> but now... let's write the energy... as it so happens, the hydrogen state energies are written as negative values

[22:55] <doos> can be anywhere between 9EO and 17EO?

[22:56] <Frank___> does this pattern last all through the n values?

[22:56] <@BrianQ> with the largest negative value having the lowest energy

[22:56] <@BrianQ> the pattern of degeneracy? yes

[22:56] <@BrianQ> oops, I gave away a clue

[22:56] <@BrianQ> !

[22:56] <@BrianQ> The hydrogen energies depend only on the principle quantum number, n

[22:57] <@BrianQ> so knowing n, you can figure the energy, and you can figure how many degenerate states lie at that energy... n^2 degeneracies

[22:58] <@BrianQ> The energy is negative, and the lowest energy is the largest negative number... so it looks like this

[22:58] <doos> -1EO for n =1 and -9EO for n=3?

[22:58] <@BrianQ> E_n (only depends on single quantum number n)

[22:58] <@BrianQ> not quite Doos :)

[22:58] <@BrianQ> E_n = -E0/n^2

[22:59] <Frank___> how can it be negative when it is n^2....squaring a negative or a positive always ends up positive

[22:59] <doos> s0 n=1: -1EO

[22:59] <@BrianQ> The ground state is n=1 (L=0, m=0)

[22:59] <doos> and n=3: 1/9th EO?

[22:59] <@BrianQ> and it has energy E_1 = -E0

[23:00] <@BrianQ> the next highest set of states is n=2 with energy E_2 = -E0/4

[23:00] <doos> -1/9th EO

[23:00] <doos> for n=3?

[23:00] <@BrianQ> the next energy.... E_3 = -E0/9

[23:01] <@BrianQ> yes

[23:01] <Frank___> do E and -E have the same number?

[23:01] <@BrianQ> What is E and -E?

[23:01] <@BrianQ> All hydrogen energy states are negative

[23:01] <Frank___> so E_4=-E0/16

[23:01] <@BrianQ> Yes,

[23:02] <@BrianQ> So time to draw a new energy level diagram....

[23:02] <Frank___> E_5=-E0/25...etc etc

[23:02] <@BrianQ> At the top of the vertical scale... is E =0

[23:02] <@BrianQ> At the bottom of the energy scale is E = E0

——————————————01[23:02] <@Spauwe> the top?

[23:02] <@BrianQ> oops, E = -E0

[23:02] <Frank___> does everyone want to screen save the blackboard if were gonna draw this

[23:03] <doos> delete the current blackboard?

[23:03] <Frank___> I've saved it

——————————————01[23:03] <@Spauwe> done

[23:03] <doos> ok

[23:03] <Frank___> I can send copies to anyone who wants them

[23:04] <@BrianQ> ok new vertical scale... with new marks...

[23:04] <@BrianQ> At the top of scale is E = 0, at the bottom is E = -E0

[23:04] <@BrianQ> halfway between top and bottom is E = -E0/2

[23:05] <doos> my fonts seem to mess up again .. Frank?

[23:05] <@BrianQ> quarter way down from top is E = -E0/4

——————————————03[23:05] * _Frank_ (i=Frank@84.4.61.238) has joined #gemology

——————————————01[23:05] <@Spauwe> like that?

[23:06] <_Frank_> am I back?

[23:06] <doos> no frank

[23:06] <_Frank_> ah good

[23:06] <@BrianQ> no Spauwe... at the top... E=0 not E=E0

01[23:07] <@Spauwe> somebody fix that

01[23:08] <@Spauwe> how do i erase just that bit?

[23:08] <@BrianQ> I will try to draw out a sketch, if you don't mind???

[23:09] <@BrianQ> Howzat?

[23:10] <doos> good

[23:10] <@BrianQ> See what is happening?

01[23:10] <@Spauwe> clear

01[23:10] <@Spauwe> yup, distances are getting smaller

[23:10] <@BrianQ> what happens to the energy spacing as n increases?

[23:10] <@BrianQ> yes

[23:10] <@BrianQ> energy spacing is getting smaller....

[23:10] <@BrianQ> a peculiar case, this hydrogen atom...

[23:11] <@BrianQ> it basically looks like a one-dimensional problem...with only one quantum number determining energy

[23:11] <@BrianQ> but there are n^2 degenerate states at each energy... a three-dimensional problem factor

[23:12] <@BrianQ> the 1-D particle in a box... energy spacing increases with n

[23:12] <@BrianQ> the 1-D simple harmonic oscilllator... energy spacing stays same with increasing n

[23:12] <_Frank_> is the top line E=0?

[23:12] <@BrianQ> yes Frank

[23:12] <_Frank_> ok

[23:12] <@BrianQ> The hydrogen atom... energy spacing decreases with n

[23:13] <@BrianQ> Because of its supersymmetry, sometimes the hydrogen atom is referred to as a quasi-one-dimensional problem

[23:14] <_Frank_> I understand the maths here but where does the extra symmetry come from?

[23:14] <@BrianQ> Its hidden ;)

[23:14] <doos> only one electron

[23:14] <@BrianQ> I done toldja

[23:14] <_Frank_> how can I visualise symmetry greater than a sphere?

[23:15] <_Frank_> or how can I visualise "hidden"?

[23:15] <@BrianQ> you can't probably, which is why I keep saying it is hidden

————————————01[23:15] <@Spauwe> ghehe

[23:15] <_Frank_> oooo this is making me mad

[23:15] <@BrianQ> it is hidden in some deep maths...

————————————01[23:15] <@Spauwe> at least you get the math...

[23:16] <_Frank_> but how can I think about it if it's hidden?

————————————01[23:16] <@Spauwe> hahaha

————————————01[23:16] <@Spauwe> think about it as dragon being here

[23:16] <@BrianQ> heh, best not to worry about it...

[23:16] <doos> think of it as an easter egg

————————————01[23:16] <@Spauwe> you don;t see here but yet she's here...

[23:16] <@BrianQ> heh

[23:16] <DragonStek> hehe

[23:17] <@BrianQ> I like the easter egg... but Frank will still keep poking around with his stick to find it

[23:17] <doos> 4 weeks after :)

[23:17] <_Frank_> a shere has better symmetry than an easter egg...but 'here there be dragons' might work

[23:17] <@BrianQ> Just take the hydrogen atom as a very special problem... many, if not most, people come upon these results without

[23:18] <@BrianQ> ever knowing there even exists a hidden symmetry...

[23:18] <doos> but now the big question

[23:18] <@BrianQ> so probably I shouldn't have mentioned it

[23:18] <doos> what if it combines to a water molecule?

[23:19] <@BrianQ> Then you lose the spherical symmetry, for sure, and the hidden symmetry, and so your quantum numbers are going to get all mixed

——————————————01[23:19] <@Spauwe> H3O?

[23:19] <doos> ah ok

[23:19] <@BrianQ> But we are going to see how we can get a rough idea of how the quantum numbers and energies should change in different situations.

[23:20] <@BrianQ> The first different situation we have to encounter is adding another electron (and proton to the nucleus) to make helium

[23:20] <doos> yes

[23:20] <@BrianQ> But anyways... a last remark.... next time, before moving to bigger atoms... we'll discuss the spectroscopy

[23:21] <doos> great ;)

[23:21] <@BrianQ> of hydrogen... of simple harmonic oscillator ... and of the particle in a box..

——————————————01[23:21] <@Spauwe> yesh... all this in relation to the foreign factor of light...

——————————————01[23:21] <@Spauwe> liking it already

[23:21] <doos> long session again today

[23:21] <_Frank_> but really a good one

[23:21] <@BrianQ> yes, the light simply makes the particle jump from one state to another...

——————————————01[23:21] <@Spauwe> yep

——————————————01[23:22] <@Spauwe> I even may be able to wrap my head around colour centres then...

[23:22] <_Frank_> Thanks Brian long as doos says but as usual fascinating

[23:22] <@BrianQ> yep... take a look at the hydrogen atom energy level diagram... see if you can draw one out...

[23:22] <@BrianQ> how many n levels can you put on your diagram before getting too close to zero?

[23:23] <doos> yes thanks Brian, nice one again

[23:23] <@BrianQ> that your pen line is too fat

[23:23] <_Frank_> as n gets higher the lines would blend into an almost silid band

[23:23] <_Frank_> no matter how large the paper you start on

[23:23] <@BrianQ> Franks last words were definitely true

[23:23] <_Frank_> am I gone then?

[23:23] <@BrianQ> oh.. that was the old "Frank" :(

————————————————————01[23:23] <@Spauwe> that was the other frank

[23:24] <_Frank_> he's a right bastid

[23:24] <@BrianQ> heh

————————————————————01[23:24] <@Spauwe> :)

[23:24] <@BrianQ> And, when you have E=0... that means the electron is free from the atom and will travel an infinite distance away...

[23:24] <@BrianQ> in other words... ionization.

[23:24] <doos> ionized?

[23:24] <doos> heh

[23:25] <@BrianQ> So the difference between E = -E0 and E = 0 is the ionization energy of hydrogen

————————————————————01[23:25] <@Spauwe> or going from valency to conduction band? No?

[23:25] <_Frank_> how high in the n value for that to happen?

[23:25] <@BrianQ> no... that's solid...

[23:25] <@BrianQ> That would be n = infinity, Frank

[23:26] <doos> so you can't really ionize a hudrogen atom?

[23:26] <_Frank_> and yet ionisation happens alla time

[23:26] <@BrianQ> Yes, you can ionize... that is beyond the context of what we are working on...

————————————————————01[23:26] <@Spauwe> yeah it would kinda stop existing

[23:26] <_Frank_> ah yes doos I see that...it would no longer be an atom...just a positive charge

[23:27] <@BrianQ> A little caveat I threw in last lecture mentions that we are only going to look at "bound" systems

[23:27] <@BrianQ> yes.

[23:27] <_Frank_> yes don't teach us to make bombs brian

[23:28] <@BrianQ> We shall keep building onto the hydrogen atom to get to multi-electron atoms, and then molecules, and then perhaps solids..

[23:28] <doos> well I know a place to drop one

[23:28] <_Frank_> lol

[23:28] <doos> heh

[23:28] <DragonStek> hehe

[23:28] <@BrianQ> hehe

[23:28] <@BrianQ> but before building... we'll investigate some spectroscopy, so we'll know why we are building :)

[23:28] <_Frank_> so next week spectroscopy and then onto multi electron atoms

[23:29] <_Frank_> sounds good

[23:29] <@BrianQ> yes indeed

[23:29] <doos> sounds good to me as well

———————————————01[23:29] <@Spauwe> sounds very good, allthough I miss a lot of the math it deepens my understanding of atoms

[23:29] <DragonStek> wow sounds good but ill reread this chat

[23:29] <@BrianQ> ciao everybody!!! Which takes more energy, jump from n=1 to n=2 or jump from n=2 to n=3?

———————————————01[23:30] <@Spauwe> depends

[23:30] <DragonStek> thanks brian another great one

[23:30] <_Frank_> read the last log Tim...the maths is easier if you go over Brians step by step build up to it

[23:30] <doos> bye BrianQ

———————————————01[23:30] <@Spauwe> will do

[23:30] <_Frank_> Bye Brian...Thanks

———————————————01[23:30] <@Spauwe> thank you and till next time

[23:30] <@BrianQ> That up there is the homework question :)

[23:30] <@BrianQ> ciao