<Spauwe> BAND GAPS AND COLOUR CAUSES

<@Spauwe> what colour has a crystal made up out of Si en 0 alone?

<@Spauwe> and Al and O

<Crystal2> clear

<Crystal2> or white depending on your take on it

<@Spauwe> and Mg Al Si and O

<@Spauwe> exactly

<@Spauwe> no colour

<@Spauwe> no wavelengths are absorbed (or redirected as we learned the next day)

<@Spauwe> as usual we ask ourselves why?

<@Spauwe> Brian is teaching us that every element's electrons can be excited

<@Spauwe> we only need what?

<DragonStek> light

<Crystal2> because there are no impurities causing color

<@Spauwe> energy, the exact right energy

<@Spauwe> which can be light

<@Spauwe> crystal: yes there's no impurities

<@Spauwe> that can offer an electron to be excited

<@Spauwe> but up to now we've looked at electrons being excited around their own nuclei or a neighboring ion's nucleus

<@Spauwe> in many materials electrons can travel through the whole lattice

<@Spauwe> (lattice being the 'building plan' of the atoms)

<@Spauwe> The atoms are held together by electronic bonding

<@Spauwe> how do we call the electrons that are busy holding on to each other?

<@Spauwe> A) transition elements

<@Spauwe> B) Valence electrons

<@Spauwe> C) Conduction electrons

<Crystal2> I vote C

<@Spauwe> D) Ionic electrons

<Crystal2> thought I waited long enough...

<@Spauwe> Dragon?

<DragonStek> ok c

<@Spauwe> buzzer going

<Crystal2> ok, D

<@Spauwe> nope

<@Spauwe> valence electrons

<@Spauwe> the electrons in the outer shell

<Crystal2> well pick one of the other two, dragon; you got 50/50 chance of being right

<Crystal2> hehe

<DragonStek> lol

<@Spauwe> let's state that the electrons that are busy holding the material together are in the 'valency band'

<@Spauwe> electrons that can wander through the whole material are called to be in the conduction band

<@Spauwe> There's a gap between the energy levels between these two bands

<@Spauwe> the difference in energy needed to push an electron from the valence band into the conduction band

<Crystal2> that's the band gap?

<@Spauwe> yep

<Crystal2> and the theory is that electrons have to jump onto something else before they can get enough energy to cross the band gap?

<@Spauwe> more or less yes

<Crystal2> ok

<@Spauwe> lets look at an example

<@Spauwe> diamond

<@Spauwe> nice and easy cause it only has one kind of element when pure

<@Spauwe> carbon

<@Spauwe> all the electrons are nicely tied up in their 'holding together the material role'

<@Spauwe> at room temperature not a single electron is able to be excited from that role

<@Spauwe> the highest energy level in visible light is unable to pull it off

<@Spauwe> the highest energy level of visible light being?

<@Spauwe> violet light

<@Spauwe> But

<@Spauwe> most diamonds contain impurities

<@Spauwe> nitrogen being one

<DragonStek> boron or nitrogen

<DragonStek> opps

<@Spauwe> nitrogen has one valence electron more than carbon

<@Spauwe> 5 against 4

<@Spauwe> so when a nitrogen atom takes the place of a carbon atom there's one electron hanging around not having a job

<@Spauwe> job less electrons

<@Spauwe> see that?

<DragonStek> yes

<Crystal2> yes

<@Spauwe> this electron actually can be excited by visual light

<@Spauwe> for this it takes mainly blue and violet light

<@Spauwe> resulting in a canary yellow residual colour

<@Spauwe> So the nitrogen acts as a donor

<@Spauwe> it's donates a spare electron to be excited into the conduction band

<@Spauwe> name another diamond impurity

<@Spauwe> hint: type IIB

<DragonStek> boron

<@Spauwe> exactly

<@Spauwe> now, boron only has 3 valence electrons

<@Spauwe> so when a boron electron takes the place of a carbon there's a shortage of one electron

<@Spauwe> in this case boron will not be the donor but rather the acceptor

<@Spauwe> a carbon electron from the valence band is 'pulled' from it's valence band

<@Spauwe> and can then be excited

<@Spauwe> for this red light is used

<@Spauwe> resulting in a blue colour

<@Spauwe> In addition to that: because there's one electron pulled from the valence band for every boron atom there's many holes created in the lattice

<@Spauwe> this results in the ability of that particular diamond to conduct electricity

<@Spauwe> unlike all other diamonds that are insulators

<@Spauwe> which allows us to use electricity conductor probes

<@Spauwe> So a natural blue wouldn't come up as a diamond when using one of them

<@Spauwe> but that just as a side note

DragonStek> so one is a good conductor and one not

<@Spauwe> questions?

<Crystal2> yes

<Crystal2> put very well, Tim

<DragonStek> oh ok

<@Spauwe> all diamonds are insulators (do not conduct) except for type IIB's the ones that contain boron

<@Spauwe> there's two kinds of diamond testers

<@Spauwe> the thermal conductivity ones

<DragonStek> so boron ,blue good conductor the other is not

<@Spauwe> and the electrical conductivity ones

<@Spauwe> yes

<DragonStek> ok i got it

<@Spauwe> if a electrical conductivity tester is telling you the blue 30ct stone you have in front of you is not a diamond don't believe it

<@Spauwe> do further testing

<@Spauwe> but back to the band gaps

<@Spauwe> the gap needs defining

<@Spauwe> the gap is the 'forbidden zone' where electrons can't be excited to

<@Spauwe> they're either in their roll as a valence electron

<@Spauwe> or excited to the conduction band

<@Spauwe> the energy level between them is that band gap

<@Spauwe> the gap can be big

<@Spauwe> the gap can be small

<DragonStek> insulators are big gaps and conductors are small gaps

<@Spauwe> don't know if there's such an connection dragon

<@Spauwe> it's the fact that the presence of boron creates a deficiency in the lattice of the diamond that creates the conductivity to take place

@Spauwe> not the band gap

<DragonStek> oh ok]

<@Spauwe> the boron 'cheats' itself somewhere in that band gap

<@Spauwe> it form's a bridge for an electron from the valence band to be excited from it where it usually couldn't do that with just visible light hitting it

<@Spauwe> with a big band gap, a gap from let's say 348nm to 789nm

<@Spauwe> what will we see?

<DragonStek> clear

<DragonStek> colorless

<@Spauwe> yes

<@Spauwe> clear is what we see

<@Spauwe> no visible light is able to excite electrons from their valance band to the conductivity band

<Crystal2> I thought boron caused the blue type IIb's

<@Spauwe> If we have a very small gap of let's say 455nm to 478nm

<@Spauwe> what will we see then?

<Crystal2> they must be the blue ones

<@Spauwe> the small band gap indicates that nearly all visible light will be able to excite electrons there

<@Spauwe> which in that case will happen as well

<@Spauwe> what happens to wavelengths that excite electrons?

<@Spauwe> or what happens to light that excites electrons?

<DragonStek> goes black or opaque

<@Spauwe> it is absorbed

<@Spauwe> and if nearly all light is absorbed it goes black or opaque

<@Spauwe> indeed

<@Spauwe> So materials with a band gap larger than the whole energy range of visible light are colourless when pure

<@Spauwe> materials with a band gap smaller then the lowest energy of visible light (or like in the last example: a very tiny gap) will appear black

<@Spauwe> and then there's the band gaps that overlap the energy range of visible light

<@Spauwe> the diamond example would fall in which when:

<@Spauwe> a type Type IIA?

<DragonStek> semi conductor

<DragonStek> insulator

<@Spauwe> forget about the conductor bit

<@Spauwe> the conductor bit was a side track

<@Spauwe> (that I shouldn't have taken)

<@Spauwe> :)

<DragonStek> oh so i dont need to know it

<@Spauwe> I'm aiming for:

<@Spauwe> big gap

<@Spauwe> small gap

<@Spauwe> overlap gap

<@Spauwe> a type IIA diamond is what kind off diamond?

<DragonStek> large gap

<@Spauwe> yes indeed

<@Spauwe> it's a pure diamond

<@Spauwe> no impurities

<@Spauwe> and it has a large band gap

<@Spauwe> and hence is colourless

<DragonStek> smaLL gap dark colors ?

<@Spauwe> small gap black

<@Spauwe> yesh

<@Spauwe> large clear

<@Spauwe> small opaque

<DragonStek> ok i think i got it now

<@Spauwe> ok

<@Spauwe> the boron containing one

<@Spauwe> will bridge the band gap

<@Spauwe> it's making it smaller

<@Spauwe> allowing electrons to be excited from their bonding role into the flying around like mad state

<@Spauwe> and thus light being absorbed

<@Spauwe> causing colour

<@Spauwe> now

<@Spauwe> trick question

<@Spauwe> Corundum has what kind of gap?

<@Spauwe> pure corundum

<DragonStek> which one, large

<@Spauwe> yesh

<@Spauwe> and pure pyrope?

<DragonStek> large

<@Spauwe> yep

<@Spauwe> pure pyrope would be colourless as well

<DragonStek> so its colorless large and darker smaller gaps

<@Spauwe> I'm yet to see a piece but theoretically it may be out there

<@Spauwe> yep you can remember it that way

<@Spauwe> Now to round up all the colour causes that we discussed lately

<@Spauwe> colour by dispersed metal ions (transition elements)

<@Spauwe> colour by charge transfers

<@Spauwe> colour by physical optics

<@Spauwe> Band gaps

<@Spauwe> and colour centres

<@Spauwe> what do you think?

<@Spauwe> will a gemstones colour be caused by just one of these causes?

<@Spauwe> so either this or that?

<DragonStek> no all

<@Spauwe> no gains you points all doesn't

<@Spauwe> a combination is often the case

<@Spauwe> the band gap theory is somewhat of a way of looking at it from a different angle

<@Spauwe> now did I clarify things to you or did I just confuse you more?

<DragonStek> it depends on the energy needed to create the color we see

<@Spauwe> yes

<DragonStek> ok then i got it

<@Spauwe> it's a mix of electrons being free to move and the right energy to get them moving

<@Spauwe> but then there's colour centres

<@Spauwe> some of which don't depend on electrons being excited at all

<@Spauwe> but at molecular vibrations like Brian taught us the other day

<@Spauwe> I'll try to sum it up in short:

<@Spauwe> dispersed metal ions:

<@Spauwe> electrons being excited around their own nucleus to a higher shell

<@Spauwe> charge transfer:

<@Spauwe> electrons being excited to a neighboring nucleus and back again

<@Spauwe> so there's two ions involved

<@Spauwe> Colour centers:

<@Spauwe> deficiencies in crystal lattices allowing all kinds of things to happen :)

<@Spauwe> physical optics:

<@Spauwe> dispersion, reflection, diffracting , interference etc

<@Spauwe> so nothing to do with the excitement of electrons

<@Spauwe> just the nature of light travelling through and around different media

<@Spauwe> and the band gap theory:

<@Spauwe> teaching us that there's a difference between electrons that are able to move freely through a lattice and electrons that are 'tied up' holding the substance together

<@Spauwe> okidokie

<DragonStek> ok

<Crystal2> nice lesson, Tim

<DragonStek> so i think im making it harder then it is

<@Spauwe> depends..

<@Spauwe> what are your thought?

<@Spauwe> thoughts?

<DragonStek> its all things i cant see

<Crystal2> heh

<@Spauwe> the results you can see:

<@Spauwe> colour

<DragonStek> and i have to trust it to know its there

<DragonStek> on how color got there

<@Spauwe> yep

<DragonStek> and how much of this is on the test

<DragonStek> alot

<@Spauwe> all these theories are nice but the reality often is a combination of some of 'm

<@Spauwe> and there's always exceptions

<DragonStek> always to throw you off

<@Spauwe> yups

<@Spauwe> can you think of a material that has a small band gap or a band gap that is lower than visible light?

<@Spauwe> in other words: is opaque when pure?

<DragonStek> jade

<DragonStek> quartz

<@Spauwe> jade is polycrystalline

<@Spauwe> and quartz is anything but opaque when pure <DragonStek> sometimes it is

<@Spauwe> then what has been the case?

<@Spauwe> we discussed that a couple of weeks ago under colour centres

<@Spauwe> when a single quartz crystal absorbs all light (and it's not because of inclusions) what happened?

<DragonStek> i dont know

<@Spauwe> it contained Al as an impurity and got irradiated

<@Spauwe> resulting in smokey

<@Spauwe> one of the electrons of the Al get's knocked out of place creating the Hole centre

<@Spauwe> if there's enough Al present and the irradiation prolongs long enough the crystal may go black completely

<DragonStek> missing electron

<@Spauwe> super smokey

<DragonStek> leaves a hole

<@Spauwe> yep it's coming back to you

<DragonStek> hay im on vacation

<@Spauwe> what happens when we chuck that black crystal in an oven?

<DragonStek> so is my brain

<@Spauwe> :)

<DragonStek> returns to the original state

<@Spauwe> yep, the displaced electrons are allowed to migrate back

<@Spauwe> and the crystal goes clear again (in theory)

<DragonStek> as long as it not over heated

<@Spauwe> well, usually there's more impurities

<@Spauwe> and it may go greenish

<@Spauwe> dunno what exactly is going on there

<@Spauwe> but back to that question:

<@Spauwe> what material is opaque when pure?

<@Spauwe> FeS_2

<@Spauwe> pyrite

<@Spauwe> and hematite

<@Spauwe> iron oxide

<DragonStek> metals

<@Spauwe> visible light can't get through it

<Crystal2> I almost said pyrite but decided against it

<Spauwe> it has a band gap outside the visible range of electromagnetic energy

<DragonStek> well you could of helped me

<@Spauwe> :)

<Crystal2> I thought it was wrong!

<@Spauwe> I wonder what's going on in tourmaline

<@Spauwe> often it's opaque in one direction

<@Spauwe> the closed C axis story

<@Spauwe> would that be a directional band gap difference?

<DragonStek> yeaah?

<@Spauwe> I dunno

<@Spauwe> good question for Brian...

<DragonStek> me either i thought you asking

<@Spauwe> No I have no clue

<DragonStek> well ask brian tomorrow

<@Spauwe> I always thought it was thickness

<@Spauwe> but it apparently isn't

<@Spauwe> spelling is going down fast...

<@Spauwe> ok

<@Spauwe> so from now on no more long winded theoretical concepts

<@Spauwe> but plain old descriptions of gem species

<Crystal2> it was a fun trip through them Tim

<@Spauwe> tips and tricks on how to ID them etc

<DragonStek> my favorite

<Crystal2> good deal

<Crystal2> excellent

<DragonStek> ok sweety

<@Spauwe> vaya con dios

<Crystal2> til next week then

<Crystal2> g'night y'all

<@Spauwe> till next week

<DragonStek> ok night

<Crystal2> have a great evening and we'll meet again tomorrow :)

<@Spauwe> any gem variety that you want first?

[00:31] <DragonStek> corundum

[00:31] <Crystal2> ok

01[00:31] <@Spauwe> corundum it is

[00:31] <DragonStek> cool

[00:31] <Crystal2> see ya'll tomorrow

———————————————01[00:31] <@Spauwe> see yous 2 morrow

[00:31] <DragonStek> see ya

Session Close: Sun Jun 29 00:31:38 2008

Session Start: Sun Jun 29 19:45:50 2008

Session Ident: #gemology

Session Close: Sun Jun 29 19:45:50 2008