3-9 Series Limits (smallest λ)

$$\frac{1}{\lambda} = R_H \left[\frac{1}{n^2} - \frac{1}{k^2}\right]$$

$k > n$

$R_H = 1.096776 \times 10^7 \ m^{-1}$

a) Balmer $n=2$

$$\frac{1}{\lambda} = R_H \left[\frac{1}{2^2} - \frac{1}{k^2}\right]$$

the smallest λ occurs for the largest value of k, so $k \to \infty$

$$\frac{1}{\lambda} = R_H \left[\frac{1}{4} - \frac{1}{\infty^2}\right]$$

$$\frac{1}{\lambda} = R_H \left[\frac{1}{4}\right]$$

$$\frac{1}{\lambda} = 1.096776 \times 10^7 \ \frac{1}{4}$$

$$\lambda = 3.64 \times 10^{-7} \ m$$

$$= 364 \ nm$$

b) Lyman $n=1$

$$\frac{1}{\lambda} = R_H \left[\frac{1}{1^2} - \frac{1}{k^2}\right]$$

similar to above $k \to \infty$

$$\frac{1}{\lambda} = 1.096776 \times 10^7 \left[\frac{1}{1}\right]$$

$$\lambda = 9.12 \times 10^{-8} \ m$$

$$= 91.2 \ nm$$

3-12 Four largest wavelengths for Brackett or Pfund

$n=4$ $n=5$

$$\frac{1}{\lambda} = R_H \left[\frac{1}{n^2} - \frac{1}{k^2}\right]$$

$k > n$

$R_H = 1.096776 \times 10^7$

Brackett n=4

n	k	1/lambda (m^-1)	lambda (m)	lambda (nm)	
4	5	246775.5	4.0523E-06	4052	Infrared
4	6	380826.389	2.6259E-06	2626	Infrared
4	7	461654.847	2.1661E-06	2166	Infrared
4	8	514115.625	1.9451E-06	1945	Infrared
4	9	550082.562	1.8179E-06	1818	Infrared

Pfund n=5

n	k	1/lambda (m^-1)	lambda (m)	lambda (nm)	
5	6	134050.889	7.4599E-06	7460	Far Infrared
5	7	214879.347	4.6538E-06	4654	Far Infrared
5	8	267340.125	3.7406E-06	3741	Far Infrared
5	9	303307.062	3.2970E-06	3297	Far Infrared
5	10	329034	3.0392E-06	3039	Far Infrared

3-14a Hubble Space Telescope can detect wavelengths of 400-700nm.

List all wavelengths of hydrogen in this range.

RH 1.10E+07

Lyman n=1

n	k	1/lambda (m^-1)	lambda (m)	lambda (nm)	
1	2	8225850	1.2157E-07	122	UV
1	3	9749155.56	1.0257E-07	103	UV
1	4	10282312.5	9.7254E-08	97	UV
1	5	10529088	9.4975E-08	95	UV
1	6	10663138.9	9.3781E-08	94	UV

Balmer n=2

n	k	1/lambda (m^-1)	lambda (m)	lambda (nm)	
2	3	1523305.56	6.5647E-07	656	VIS
2	4	2056462.5	4.8627E-07	486	VIS
2	5	2303238	4.3417E-07	434	VIS
2	6	2437288.89	4.1029E-07	410	VIS
2	7	2518117.35	3.9712E-07	397	edge of VIS

Paschen n=3

n	k	1/lambda (m^-1)	lambda (m)	lambda (nm)	
3	4	533156.944	1.8756E-06	1876	Infrared
3	5	779932.444	1.2822E-06	1282	Infrared
3	6	913983.333	1.0941E-06	1094	Infrared
3	7	994811.791	1.0052E-06	1005	Infrared
3	8	1047272.57	9.5486E-07	955	Infrared

3-17 λ_{max} of Blackbody Spectrum

Wein Displ: $\lambda_{max} = \frac{2.898 \times 10^{-3}\ m \cdot K}{T}$

a) liquid Helium $T = 4.2\ K$

$\lambda_{max} = 6.90 \times 10^{-4}\ m$

microwaves

b) Room temperature $T = 293\ K$

$\lambda_{max} = 9.89 \times 10^{-6}\ m$

$= 9890\ nm$

infrared

c) steel furnance $T = 2500\ K$

$\lambda_{max} = 1.16 \times 10^{-6}\ m$

$= 1160\ nm$

3-20

a) At what wavelength does human body radiate maximally?

$T = 37°C = 310\ K$

$$\lambda_{max} = \frac{2.898\times10^{-3}}{T} = \frac{2.898\times10^{-3}}{310}$$

$$= 9.35\times10^{-6}$$

$$\sim 9350\ nm$$

b) Estimate power radiated if assume human is cylinder

Stefan Boltzmann

$$\text{Intensity} = \epsilon\sigma T^4$$

Take $\epsilon = 1$

$\sigma = 5.6705\times10^{-8}$

$$\text{Intensity} = (1)(5.67\times10^{-8})(310)^4$$

$$= 524\ \text{Watts}/m^2$$

$$\text{Surface Area of cylinder} = \overset{\text{ends}}{2\pi r^2} + \overset{\text{side}}{2\pi r h}$$

$$= 2\pi(0.13)^2 + 2\pi(0.13)(1.65)$$

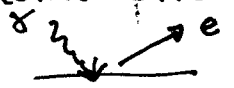
$$= 1.45\ m^2$$

then power = intensity * area

$$= \left(524\ \frac{\text{Watts}}{m^2}\right)(1.45\ m^2)$$

$$= 761\ \text{Watts}$$

3-34 Photo electric effect Lithium $\phi = 2.93\ eV$



a) threshold frequency.

The incident photo must have at least enough energy to overcome the binding of the electron.

$$hf = 2.93 \qquad \text{convert to J}$$

$$(6.626\times10^{-34})f = 2.93\ eV\left(1.602\times10^{-19}\ \frac{J}{eV}\right)$$

$$f = 7.08\times10^{14}\ Hz$$

b) What is stopping potential if $\lambda = 400\ nm$ light shined on lithium?

This is basically asking about the kinetic energy of the ejected electron

So energy of photon $= hf = \frac{hc}{\lambda}$

$$= \frac{(6.626\times10^{-34})(3\times10^8)}{400\times10^{-9}}$$

$$= 4.97\times10^{-19}\ \text{Joules}$$

$$= 3.10\ eV$$

Then $KE = hf - \phi$

$$= 3.10 - 2.93$$

$$= 0.17\ eV$$

To stop a $KE = 0.17\ eV$ electron requires a voltage of 0.17 Volts

3-43

Bremsstralung

– 20,000 V –

The maximum KE of electrons is 20,000 eV

If all of this energy were converted to the X-ray energy

$$20{,}000 \text{ eV} = hf$$

$$\underbrace{(20{,}000)(1.602\text{-}19)}_{\text{Joules}} = \frac{hc}{\lambda}$$

$$3.2\times10^{-15} = \frac{(6.626\times10^{-34})(3\times10^{8})}{\lambda}$$

$$\lambda = 6.2\times10^{-11} \text{ m}$$

3-48

– Seriously?

$$KE = hf$$

$$\underbrace{(6\times10^{3})(1.602\text{-}19)}_{\text{Joules}} = \frac{hc}{\lambda}$$

$$9.61\times10^{-16} = \frac{(6.626\times10^{-34})(3\times10^{8})}{\lambda}$$

$$\lambda = 2.068\times10^{-10} \text{ m}$$

Then the Compton formula is

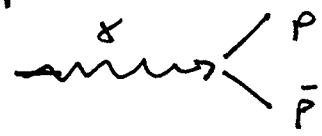
$$\Delta\lambda = \lambda' - \lambda = \frac{h}{mc}(1-\cos\theta)$$

$$= \frac{6.626\times10^{-34}}{(1.67\times10^{-27})(3\times10^{8})}\left[1-\cos 90^{\circ}\right]$$

$$\Delta\lambda = \lambda' - \lambda = 1.38\times10^{-15} \text{ m}$$

Actually since we were asked for the change in λ, we didn't have to to that first part up top.

3-54 How much energy required to produce a proton - antiproton pair?



the incident photon would have to have twice the rest mass energy.

$$\text{photon energy} = 2\,(938\,\text{MeV})$$
$$= 1876\ \text{MeV}$$

A photon of this energy would have to be a by product of a reaction in a large elementary particle accelerator.

Maybe also at the RHIC on Long Island.