Φ2020:
27: 6, 23, 33, 51, 65   28: 1, 5, 19   29: 5, 33, 53, 57

⑥ IRONMAN's very shiny armor is illuminated by ultraviolet light. No photoelectrons are ejected until $\lambda < 288\text{nm}$. (a) What is the work function of the metal? (b) What is the max K_E when $\lambda = 140\text{nm}$?

(a) The photoelectric effect is:

$$K_E = E_\gamma - \phi$$

At the cutoff frequency $\lambda_c = 288\text{nm}$ then $K_E = 0$ so//

$$E_\gamma = \phi \rightarrow \frac{hc}{\lambda} = \phi$$

so//

$$\phi = \frac{4.136 \times 10^{-15}\,\text{eVs} \cdot 3.0 \times 10^{8}\,\text{m/s}}{288 \times 10^{-9}\,\text{m}} = \boxed{4.308\,\text{eV}}$$ (ANS)

(b) For 140nm photons:

$$K_E = E_\gamma - \phi = \frac{hc}{\lambda} - \phi$$

$$= \frac{(4.136 \times 10^{-15}\,\text{eVs}) \cdot 3.0 \times 10^{8}\,\text{m/s}}{140 \times 10^{-9}\,\text{m}} - 4.308\,\text{eV}$$

$$\boxed{= 4.555\,\text{eV}}$$ (ANS)

(23) An x-ray photon with $\lambda = 0.150\,nm$ collindes with an electron that is at rest and minding its own business. The scattered photon travels at 80° to original direction. What is the compton shift and final wavelength?

The Compton shift formula is: $\Delta\lambda = \lambda_f - \lambda_i = \frac{h}{mc}(1-\cos\theta)$

Sol//

$$\Delta\lambda = \frac{6.626\times10^{-34}\,Js}{(9.11\times10^{-31}\,kg)(3\times10^{8}\,m/s)}(1-\cos 80°) = 2.00\times10^{-12}\,m$$

Sol//

$$\lambda_f = \lambda_i + \Delta\lambda = 0.150\times10^{-9}\,m + 2.00\times10^{-12}\,m$$

$$\boxed{\lambda_f = 1.52\times10^{-10}\,m = 0.152\,nm}$$ (ANS)

(33) What are the difference in radii between $n=1$ and $n=2$ in hydragen? (b) Between $n=100$ and $n=101$?

The radii of orbits may be expressed in terms of the Bohr radius a_0:

$$r_n = n^2 \cdot a_0$$

so//

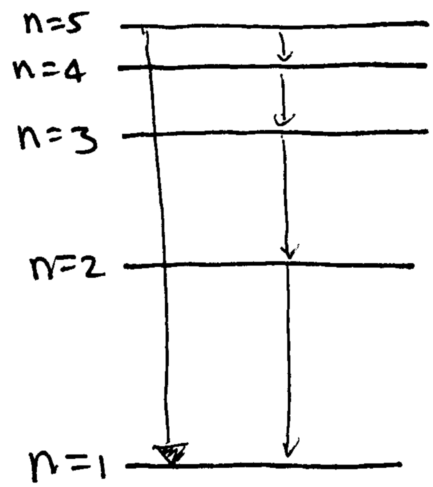
$n=1$	$r_n = 1^2 \cdot 0.529 \times 10^{-10} m =$	$5.29 \times 10^{-11} m$
$n=2$	$r_n = 2^2 \cdot 0.529 \times 10^{-10} m =$	$2.116 \times 10^{-11} m$
$n=100$	$r_n = 100^2 \cdot 0.529 \times 10^{-10} m =$	$5.29 \times 10^{-7} m$
$n=101$	$r_n = 101^2 \cdot 0.529 \times 10^{-10} m =$	$5.40 \times 10^{-7} m$

At large values of n, the difference in orbital radii are small ratios compared to larger valres of n. To be explicit:

$$\frac{r_{n+1}}{r_n} = \frac{(n+1)^2 a_0}{n^2 a_0} = \frac{(n+1)^2}{n^2} = \left(1+\frac{1}{n}\right)^2$$

when n is small $1/n$ is BIG, so the orbital radii difference is larger. when n is BIG $1/n$ is SMALL and the orbital radii are about the same.

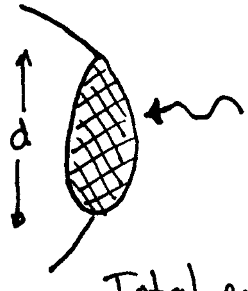
(57) A hydrogen atom is watching the Jazz trounce Houston, so is in the $n=5$ excited state. Suppose it returns to the ground state, what are the MIN and MAX number of photons emitted?



MIN: The minimum # is 1, for a direct transition from $n=5 \rightarrow n=1$.

MAX: The max # is 4, for single state transitions from $n=5 \rightarrow n=4 \rightarrow n=3 \rightarrow n=2 \rightarrow n=1$

(65) An owl can detect an intensity of 5.0×10^{-13} W/m^2. At 510 nm, how many photons per second are required to see if the pupil has a diameter of 8.5 mm?



- The area of the pupil is: $A = \pi r^2 = \pi \left(\frac{D}{2}\right)^2$
- Intensity is related to power, which is related to the total energy: $I = P/A = (E/t)/A = \dfrac{E}{A \cdot t}$

Total energy on pupil then is: $E_{TOT} = IAt = \pi \left(\frac{D}{2}\right)^2 It$

Given for 1 photon $E = hc/\lambda$ then:

$$\#\text{PHOTONS} = \frac{E_{TOT}}{E} = \frac{\pi (D/2)^2 It}{hc/\lambda} = \frac{\pi \lambda D^2 It}{4hc} = \boxed{73 \text{ photons}}$$

(ANS)

① In an average Jazz playoff game, a 0.50kg basketball moves at 10 m/s. What is the deBroglie λ and why don't we see diffraction when the ball passes thru the aperture of the hoop?

The deBroglie λ is: $\lambda = \frac{h}{p} = \frac{h}{mv}$

So//

$$\lambda_{BB} = \frac{6.626\times10^{-34}\,J\cdot s}{0.50kg \cdot 10\,m/s} = \boxed{1.33\times10^{-34}\,m}$$ (ANS)

We see no diffraction because aperture is HUGE compared to wavelength.

⑤ Suppose I'm walking along one day and find a 0.100 keV photon and 0.100 keV electron. What is their wavelength ratio?

For photons: $E = hc/\lambda$

For electrons: $E = K_E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ and $\lambda = \frac{h}{p}$

So solving for electron: $E = \frac{p^2}{2m} \rightarrow p^2 = 2mE \rightarrow p = \sqrt{2mE}$

solving for photon: $E = hc/\lambda \rightarrow \lambda = hc/E$

So//

$$\frac{\lambda e}{\lambda p} = \frac{h/p}{hc/E} = \frac{h}{p}\cdot\frac{E}{hc} = \frac{E}{\sqrt{2mE}\cdot c} = \sqrt{\frac{E}{2mc^2}}$$

So//

$$\frac{\lambda e}{\lambda p} = \left[\frac{0.10\times10^{3}\,eV\cdot 1.602\times10^{-19}\,J/eV}{2\cdot9.11\times10^{-31}\,kg\cdot(3.0\times10^{8}\,m/s)^2}\right]^{1/2} = \boxed{9.88\times10^{-3}}$$ (ANS)

(19) At a baseball game you and I use our homebuilt radar gun to measure speed of a baseball to be 137.32 ± 6.10 km/h. If a baseball masses 144g (a) What is position uncertainty? (b) What if it were a proton instead?

The uncertainty principle states: $\Delta x \cdot \Delta p \leq \frac{1}{2}\hbar$

I write momentum uncertainty as: $\Delta p = m\Delta v$ where Δv is the uncertainty in velocity.

so//

$$\Delta x \leq \frac{\hbar}{2m\Delta v} = \frac{1.055\times10^{-34}\,J\cdot s}{2(0.144\,kg)(0.10\,\frac{km}{h})(\frac{1\,h}{3600\,s})(\frac{1000\,m}{1\,km})}$$

$$\boxed{\Delta x \leq 1.32\times10^{-32}\,m}$$ (ANS)

Not very uncertain — you and I know that ball was in the strike zone.

For a proton:

$$\Delta x \leq \frac{\hbar}{2m\Delta v} = \frac{1.055\times10^{-34}\,J\cdot s}{2(1.673\times10^{-27}\,kg)(0.10\,\frac{km}{h})(\frac{1\,h}{3600\,s})(\frac{1000\,m}{1\,km})}$$

$$\boxed{\Delta x \leq 1.13\times10^{-6}\,m}$$ (ANS)

Substantially more uncertain! Though still not so much from our view out in the left field nosebleed seats.

(5) What is symbol for potassium isotope with 21 neutrons?

Potassium is ${}_{19}K$ ($Z=19$ protons) so the atomin number is
$A = Z + N = 19 + 21 = 40$ so//

$\boxed{{}^{40}_{19}K}$ (ANS) POTASSIUM40

Potassium 40 decays naturally to stable ${}^{40}Ar$ in about 1.25×10^{9} yrs and is commonly used to date rocks.

(33) A sample of radioactive kryptonite has a half life of 200.0s. The activity of the sample is initially 80000 s^{-1}. (a) What is the activity after 600s? (b) How many nuclei were there initially? (c) What is the probability per second a nuclei decays?

• I get decay constant from half-life: $\lambda = \frac{\ln 2}{\tau_{1/2}} = \frac{\ln 2}{200.0s} = 3.466\times10^{-3}s^{-1}$
this is the probability per time of a decay.

(a) $R = R_0 e^{-\lambda t} = 80000s^{-1} \cdot \text{EXP}\left[-(3.466\times10^{-3}s^{-1})(600s)\right] = \boxed{10000s^{-1}}$ (ANS)

(b) $N = R/\lambda$ so// $N_0 = R_0/\lambda = \frac{80000s^{-1}}{3.466\times10^{-3}s^{-1}} = \boxed{2.31\times10^{7}\text{ NUCLEI}}$ (ANS)

(c) The probability of a decay per second is simply λ:

$\boxed{\lambda = 3.466\times10^{-3}s^{-1}}$ (ANS)

(53) A common uranium decay path is: $^{235}U + n \rightarrow {}^{141}Cs + {}^{93}Rb + x \cdot n$
(a) What is "x"? (b) How much energy is released? (c) What fraction of ^{235}U rest energy is released?

(a) The full reaction with properly balanced neutrons is:

$$^{235}_{92}U + n \rightarrow {}^{93}_{37}Rb + {}^{141}_{55}Cs + 2n \qquad \boxed{x = 2} \text{ (ANS)}$$

(b) The component masses are:

n: 1.008665u
^{235}U : 235.043925u
^{93}Rb : 92.9220428 u
^{141}Cs : 140.9200461 u

so// $m_i = 236.052590u$
$m_f = 235.859419u$

$\Delta m = m_f - m_i = (-)0.193171u$

so//

$$\Delta E = \Delta mc^2 = (-)0.193171u \cdot c^2 \left(\frac{931.5 \text{ MeV}/c^2}{1u}\right) = \boxed{179.9 \text{ MeV}} \text{ (ANS)}$$

(c) The ^{235}U rest energy: $E_U = mc^2 = (235.043925u)c^2\left(\frac{931.5 \text{ MeV}/c^2}{1u}\right)$

so//

$$E_U = 2.1894 \times 10^5 \text{ MeV} = 0.2189 \text{ GeV}$$

so//

$$\frac{\Delta E}{E_U} = 8.2 \times 10^{-4} \Rightarrow \boxed{0.08\%} \text{ (ANS)}$$

(57) Consider: $^1_1H + ^2_1H \rightarrow X$.
(a) What is X? (b) If the binding energy of ^2H is 1.1 MeV per nucleon and of X is 2.6 MeV/nucleon, how much energy is released? (c) Why can't your average mad scientist get this reaction to work at room temperature?

(a) There are no neutrons, so atomic number is conserved:

$1+1=2$ so $Z_X = 2 \therefore X = He$

The mass number is $1+2=3$ so// $\boxed{X = ^3_2He}$ (ANS)

(b) The binding energies are:

^1_1H: $BE = 0$

^2_1H: $BE = 2\text{ nucleons} \cdot 1.1\text{ MeV/nucleon} = 2.2\text{ MeV}$

^3_2He: $BE = 3\text{ nucleons } 2.6\text{ MeV/nucleon} = 7.8\text{ MeV}$

So// $\Delta E = 7.8\text{ MeV} - 2.2\text{ MeV} = \boxed{5.6\text{ MeV}}$ (ANS)

(c) At room temperature, the KE speeds are slow like your professor, and cannot overcome the coulomb repulsion in the nuclei.