HOMEWORK 9 SOLUTIONS

7-41) (a) Cl $\Rightarrow$ $Z = 17$ $\quad (1s)^2(2s)^2(2p)^6(3s)^2(3p)^5$

(b) Ca $\quad Z = 20$ $\quad (1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(4s)^2$

(c) Ge $\quad Z = 32$ $\quad (1s)^2(2s)^2(2p)^6(3s)^2(3p)^6(4s)^2(3d)^{10}(4p)^2$

7-44) The energy goes like Z_{eff}^2 $\Rightarrow$ $\quad E = -13.6\,eV\left(\frac{Z_{eff}^2}{n^2}\right)$

So

$$Z_{eff} = \left(\frac{E}{-13.6}\right)^{1/2} n = \left(\frac{-5.14\,eV}{-13.6\,eV}\right)^{\frac{1}{2}}(3) = \boxed{1.84}$$

7-51) The selection rules are $\Delta l = \pm 1$, $\Delta j = 0, \pm 1$

$4S_{1/2} \to 3S_{1/2}$	doesn't occur	violates Δl rule	$(\Delta l = 0)$
$4S_{1/2} \to 3P_{3/2}$	OK		
$4P_{3/2} \to 3S_{1/2}$	OK		
$4D_{5/2} \to 3P_{1/2}$	doesn't occur	violates Δj rule	$(\Delta j = 2)$
$4D_{3/2} \to 3P_{1/2}$	OK		
$4D_{3/2} \to 3S_{1/2}$	doesn't occur	violates Δl rule	$(\Delta l = 2)$

7-54) (a) The electron energy in the 3s state is $-5.14\,eV$. From Fig. 7.22, the transitions from 3p to 3s have wavelengths of 588.99 and 588.59 nm $\Rightarrow$ using the average 588.79 we have

$$E = hc/\lambda = 1240\,eV.nm / 588.79\,nm = 2.106\,eV$$

so $\quad E(3p) = -5.14\,eV + 2.106\,eV = -3.034\,eV$

To get from 3p to 3d the wavelengths are 814.91 and 818.33 nm (average 816.6) $\Rightarrow$ $\quad E = 1240\,eV\cdot nm / 816.6\,nm = 1.52\,eV$

$$E(3d) = -3.034\,eV + 1.52\,eV = -1.516\,eV$$

$\Rightarrow$

$$\boxed{E(3s) = -5.14\,eV \;;\; E(3p) = -3.034\,eV \;;\; E(3d) = -1.516\,eV}$$

(b) As in 7-44 above $Z_{eff} = \left(\frac{E}{-13.6eV}\right)^{1/2} \cdot n$

$\Rightarrow$

$$\boxed{\begin{array}{l} 3s \Rightarrow Z_{eff} = 1.84 \\ 3p \Rightarrow Z_{eff} = 1.42 \\ 3d \Rightarrow Z_{eff} = 1.002 \end{array}}$$

(c) $-13.6eV/n^2$ is pretty good for the 3d state.

7-63) (a) $E = hc/\lambda$ $\quad E_1 = \frac{1240eV \cdot nm}{766.41\,nm} = \underline{1.6179eV}$; $E_2 = \frac{1240eV \cdot nm}{769.90nm} = \underline{1.6106eV}$

(b) $\Delta E = 1.6179eV - 1.6106eV = \boxed{0.0073eV}$

(c) The electron's magnetic moment is $\vec{\mu} = -g \cdot \left(\frac{e}{2m}\right)\vec{S}$, so $\mu_z = -g\left(\frac{e}{2m}\right)\left(\pm\frac{1}{2}\hbar\right)$ for $S_z = m_s\hbar$ with $m_s = \pm\frac{1}{2}$. The magnetic energy is $V_{mag} = -\vec{\mu} \cdot \vec{B}$ so for $\vec{B}$ along the z axis

$$V_{mag} = g\left(\frac{e}{2m}\right)\left(\pm\frac{1}{2}\hbar\right)B = \pm\frac{g}{2}\left(\frac{e\hbar}{2m}\right)B$$

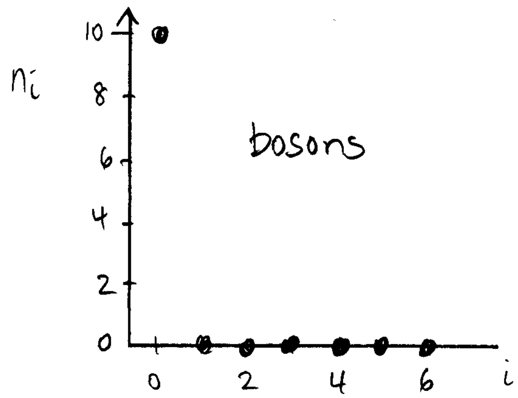
The energy difference between the two states is then

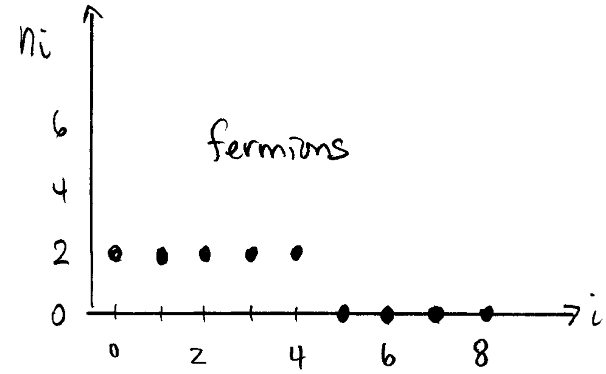
$$\Delta V = 2\left(\frac{g}{2}\right)\left(\frac{e\hbar}{2m}\right)B = g\,\mu_B\,B$$

Using $g = 2$, $\mu_B = 9.274 \times 10^{-24}\,J/T = 5.79 \times 10^{-5}\,eV/T$ we get

$$B \simeq (0.0073eV)/(2)(5.79 \times 10^{-5}\,eV/T) = \boxed{63\text{ Tesla}}$$

E-17) (a) At $T=0$ we put the particles into the lowest possible energy states. Fermions satisfy the Pauli principle, so we can only have one in each quantum state $\Rightarrow$ 2 at each energy. Bosons can occupy the same state so at $T=0$ all will be in the ground state



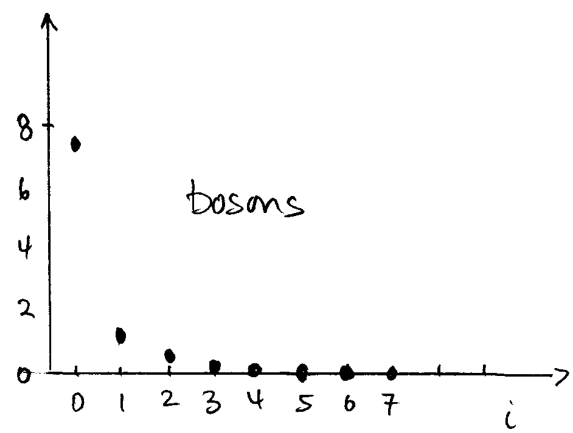


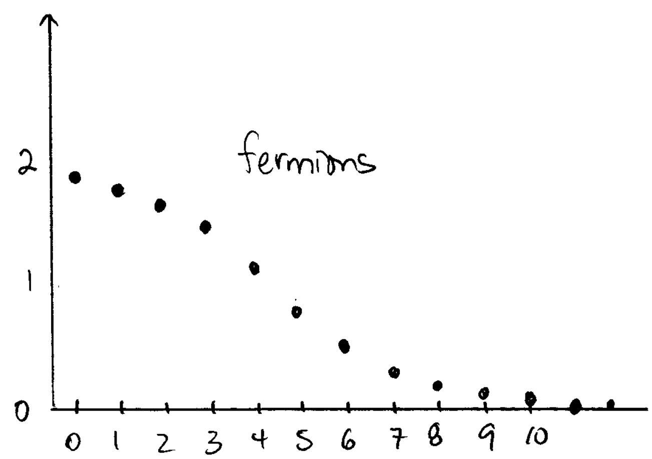
(b) Here we use the formulas to calculate n_i

$$n_i = \frac{g_i}{e^{\alpha} e^{E_i/kT} \pm 1} \qquad \text{where} \quad E_i = (i + \tfrac{1}{2})\hbar\omega_0 \ \ \& \ \ kT = \tfrac{3}{2}\hbar\omega_0$$

Here are the n_i values

	Bosons	Fermions
$i=0$	7.626	1.902
1	1.371	1.817
2	0.528	1.673
3	0.240	1.448
4	0.117	1.148
5	0.058	0.817
6	0.029	0.524
7	0.015	0.308
8	0.008	0.171
9	0.004	0.092
10	0.002	0.048
11	0.001	0.025
12	9.999 ✓	0.013
13		0.007
14		0.003
15		0.002
		9.998 ✓





8-18) Although it doesn't say, I think we are supposed to assume room temperature, $\Rightarrow$ $kT \simeq 0.025\,eV$. We are also assuming that the density is low enough so that we can use Maxwell-Boltzmann statistics. Then the formulas 8-68 apply $\Rightarrow$

$$\frac{N}{V} = 2\,\frac{(2\pi m kT)^{3/2}}{h^3}\,e^{-\alpha} = 2\left(\frac{2\pi m kT}{h^2}\right)^{3/2} e^{-\alpha} = 2\left(\frac{2\pi mc^2\,kT}{(hc)^2}\right)^{3/2} e^{-\alpha}$$

(a) $$\frac{N}{V} = 2\left[\frac{2\pi(5.11\times10^5 eV)(0.025 eV)}{(1240 eV\cdot nm)^2}\right]^{\frac{3}{2}}(1) = 2.4\times10^{-2}/nm^3$$

$$\boxed{\frac{N}{V} = 2.4\times10^{25}/m^3}$$

(b) For $e^{-\alpha} = 10^{-6}$ we get $\boxed{\frac{N}{V} = 2.4\times10^{19}/m^3}$

9-2) From Table 9-2 the dissociation energy of NaCl is 4.27 eV.
Suppose we do $2\,Na + Cl_2 \rightarrow 2\,NaCl$
It requires 2.48 eV to dissociate the Cl_2 and then we gain 4.27 eV making each NaCl, so the net energy gain is

$$2\times 4.27\,eV - 2.48\,eV = 6.06\,eV$$

$\boxed{\text{The reaction is exothermic}}$

The energy released per NaCl molecule produced is $\boxed{3.03\,eV}$

9-5) (a) $$E = \frac{e^2}{4\pi\epsilon_0}\cdot\frac{1}{r} = \frac{1.44\,eV\cdot nm}{0.267\,nm} = \boxed{+5.39\,eV}$$

(b) To make KCl out of K and Cl we supply 4.34 eV to ionize K, get back 3.62 eV attaching the electron to Cl and gain 5.39 eV from attraction, so the net gain would be $-4.34\,eV + 3.62\,eV + 5.39\,eV = 4.67\,eV$
Neglecting repulsion we predict a dissociation energy of $\boxed{4.67\,eV}$

(c) The measured energy is 4.43 eV so the energy from repulsion must be $\boxed{0.24\,eV}$

9-12) For purely ionic bond $p = (1.602\times10^{-19}C)\cdot(0.0917\,nm) = 1.47\times10^{-29}\,C\cdot m$. % ionic $= \frac{6.4\times10^{-30}}{1.47\times10^{-29}} = \boxed{43.6\%}$