Answers to some of the exercises 2019.

1a $\sigma = 5 \cdot 10^6$ m^{-1}
1b $\lambda = 2000$ Å = 200 nm
1c $\Delta E = 6.2$ eV
1d 1 eV = 8066 cm^{-1}

2 100 Å: $f = 3 \cdot 10^{16}$, $\Delta f = 1.5 \cdot 10^{13}$, $R = 5 \cdot 10^{-4}$.
1000 Å: $f = 3 \cdot 10^{15}$, $\Delta f = 1.5 \cdot 10^{11}$, $R = 5 \cdot 10^{-5}$.

4b $f\,(50 - 51) = 51.1$ GHz
4c $r_{50} = a_0 \cdot 50^2 = 0.13$ µm
4d $f = 52.7$ GHz (compare with 4b!)

5 $\lambda_{min} = 911.8$ Å, $\lambda_{max} = \infty$

6 H: Balmer series, $n = 2 - m = 3, 4, 5, 6$.
He: $n = 4 - m = 6, 7, 8, 9, 10$.

11b. For example: $L = 1$ and $M = 1$

$$\left|1,2,1,1\right\rangle = C(1,1,2,0:1,1)\cdot\left|1,1\right\rangle\cdot\left|2,0\right\rangle + C(1,0,2,1:1,1)\cdot\left|1,0\right\rangle\cdot\left|2,1\right\rangle + C(1,-1,2,2:1,1)\cdot\left|1,-1\right\rangle\cdot\left|2,2\right\rangle =$$

$$\frac{1}{\sqrt{10}}\cdot\left|1,1\right\rangle\cdot\left|2,0\right\rangle - \sqrt{\frac{3}{10}}\cdot\left|1,0\right\rangle\cdot\left|2,1\right\rangle + \sqrt{\frac{3}{5}}\cdot\left|1,-1\right\rangle\cdot\left|2,2\right\rangle$$

16 B(2s) = 0, B(2p) = 8.3 and 3400 T in He II and F IX, respectivlely!!

18. λ (1/2-3/2) = 303.77681 Å, λ (1/2-1/2) = 303.78221 Å.

19a 43487.19 cm^{-1}

19b 43487.19 cm^{-1}

19c 12204 cm^{-1}

19d 12186 cm^{-1}

20 198305 cm^{-1}

21a $T_{3s} = 639011$ cm^{-1}

21b $\delta_{4s} = 0.098$, $\delta_{4p} = 0.027$, $\delta_{4d} = 0.0017$, $\delta_{4f} = 0.00029$

22 With $\delta = 0.03$ 3s gives 3162180 cm^{-1} and 4s 3162300 cm^{-1}. NIST (3162423 ± 2) cm^{-1}.

24a 3950352 cm^{-1}

24b 3292110 cm^{-1}

24c $3127370\ cm^{-1}$ (Numerical CFA $3163975\ cm^{-1}$, experimental $(3162408 \pm 20)\ cm^{-1}$)

26a $^3P_{0,1,2}$ and $^1P_1$

26b In Mg I but not so well in Fe XV

26c $3s^2\ ^1S_0 - 3s3p\ ^3P_1$ is a so-called interconbination line where $\Delta S \neq 0$. This, together with the result above, signals that the *LS*-approximation is less valid in Fe XV. However, it is much more likely to be valid in the neutral Mg I, hence the intercombination line would not show up.

28a $sp \rightarrow {}^1P_1$ and $^3P_{0,1,2}$. $pp' \rightarrow {}^1S_0$, $^1P_1$, $^1D_2$, $^3S_1$, $^3P_{0,1,2}$ and $^3D_{1,2,3}$

28b $^1P_1$ - $^1S_0$, $^1P_1$, $^1D_2$. $^3P_{0,1,2}$ - $^3S_1$, $^3P_0$ - $^3P_1$, $^3P_1$ - $^3P_{0,1,2}$, $^3P_2$ - $^3P_{1,2}$ $^3P_0$ - $^3D_1$, $^3P_1$ - $^3D_{1,2}$, $^3P_2$ - $^3D_{1,2,3}$.

29a p^2: $^1S_0$, $^1D_2$ and $^3P_{0,1,2}$. pd: $^1P_1$, $^1D_2$, $^1F_3$, $^3P_{0,1,2}$, $^3D_{1,2,3}$, $^3F_{2,3,4}$

29b. $^1S_0$ - $^1P_1$. $^1D_2$ - $^1P_1$, $^1D_2$, $^1F_3$. $^3P_0$ - $^3P_1$,$^3D_1$. $^3P_1$ - $^3P_{0,1,2}$, $^3D_{1,2}$. $^3P_2$ - $^3P_{1,2}$, $^3D_{1,2,3}$.

30a $^1P_1$ and $^3P_{0,1,2}$

30c $(1/2,1/2)_{0,1}$ and $(3/2,1/2)_{1,2}$. Note the same *number* of levels and the same *total* *J*-values.

32. $0.0106\ s^{-1}$

35a $g_j\,(^2S_{1/2}) = 2$, $g_j\,(^2P_{1/2}) = 2/3$ and $g_j\,(^2P_{3/2}) = 4/3$

35d $\Delta E = \frac{2}{3}\mu_B B = 6{,}10 \cdot 10^{-24}\ \text{J} = 38{,}6\ \mu\text{eV} = 0{,}31\ \text{cm}^{-1}$

35e $B \approx 50$ T. This is just a crude estimate since the Zeeman approximation is not valid at such high fields. It gives, however, a feeling for what a strong/weak field is.

37 $A_{8p} = 16.26$ MHz, $A_{6s} = 1696.8$ MHz

38. Both isotopes have a spin of 3/2.

40. $\beta(3d4s\ ^3D) = 7{,}2\ cm^{-1}$, $\beta(3d4p\ ^3D) = 13{,}4\ cm^{-1}$.

42a 1.2985 Å in both isotopes

42b $f\,(35) = 8.6564 \cdot 10^{13}$ Hz, $f\,(37) = 8.6502 \cdot 10^{13}$ Hz