Homework #5 Ryan Coyne

1. The spectral lines emitted by hydrogen are a result of electrons transitioning between discrete energy levels. The radiation emitted by hot metal is blackbody radiation which is continuous.

4. $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = \frac{1}{R\lambda}$

$\lambda = 657nm: \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = \frac{1}{1.0973732 \times 10^7 \cdot 657 \times 10^{-9}}$

$= 0.1387$

$\approx \frac{1}{4} - \frac{1}{9}$

The transition is therefore from $n=3$ to $n=2$

$\lambda = 487nm: \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = \frac{1}{10973732 \cdot 487 \times 10^{-9}}$

$= 0.187$

$\approx \left(\frac{1}{4} - \frac{1}{16}\right)$

Then transition from $n=4$ to $n=2$.

$\lambda = 435nm: \left(\frac{1}{n^2} - \frac{1}{n_i^2}\right) = \frac{1}{1.0973732 \cdot 4.35}$

$= 0.209$

$\approx \frac{1}{4} - \frac{1}{25}$

transition from $n=5$ to $n=2$

$\lambda = 411nm: \left(\frac{1}{n^2} - \frac{1}{n_i^2}\right) = \frac{1}{1.0973732 \cdot 4.11}$

$= 0.222$

$\approx \frac{1}{4} - \frac{1}{36}$

transition from $n=6$ to $n=2$.

Spectra

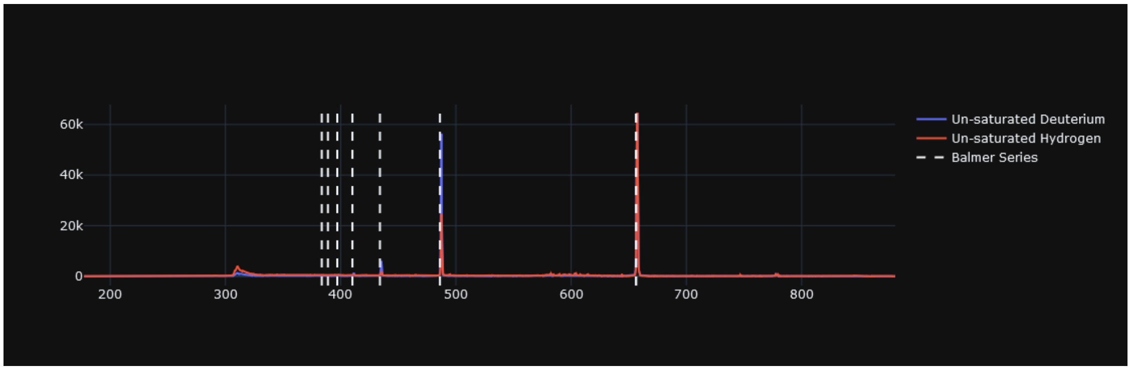
October 18, 2023

[1]:
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import plotly.graph_objects as go
```

[2]:
```
h1 = pd.read_csv("hydrogen_1.csv")
h2 = pd.read_csv("hydrogen_2.csv")
d1 = pd.read_csv("deuterium_1.csv")
d2 = pd.read_csv("deuterium_2.csv")
neon = pd.read_csv("neon_1.csv")
```

2.

[25]:
```
fig = go.Figure(data=[
    go.Scatter(x=d2.Wavelength, y=d2.Intensity, name=r'Un-saturated Deuterium'),
    go.Scatter(x=h2.Wavelength, y=h2.Intensity, name=r'Un-saturated Hydrogen'),
    go.Scatter(x=[None], y=[None], name="Balmer Series",␣
 ↪line=dict(color="white", dash='dash'), mode='lines')
])
fig.add_vline(x=383.5384, line_dash='dash')
fig.add_vline(x=388.9049, line_dash='dash')
fig.add_vline(x=397.0072, line_dash='dash')
fig.add_vline(x=410.174, line_dash='dash')
fig.add_vline(x=434.047, line_dash='dash')
fig.add_vline(x=486.133, line_dash='dash')
fig.add_vline(x=656.272, line_dash='dash')
fig.add_vline(x=656.2852, line_dash='dash')
fig.show()
```

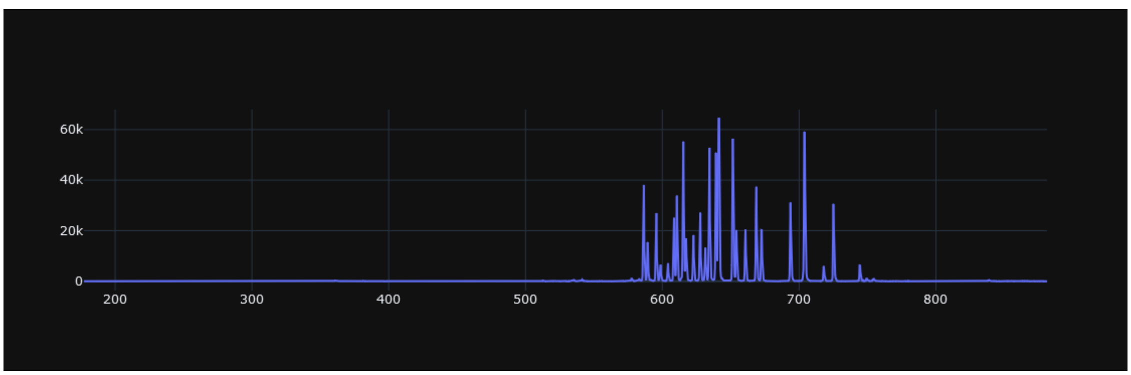


3

The equation which describes the wavelength of an emitted photon is $\frac{1}{\lambda} = \frac{ke^2}{2a_0hc}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$. This equation does not depend on the mass of the nucleus, and therefore the emission spectrum should also not depend on the mass of the nucleus.

6.

[24]:
```
fig = go.Figure(data=go.Scatter(x=neon.Wavelength, y=neon.Intensity,␣
    ↪name=r'Neon'))
fig.show()
```



7. (a) $r_1 = \frac{1^2 \hbar^2}{m_e k e^2}$

$= \frac{(6.58 \times 10^{-16} eV \cdot s)^2}{0.511 \times 10^6 eV/c^2}$

$= 0.0529 nm$

$r_2 = 2^2 r_1$

$= 0.2116 nm$

$r_3 = 3^2 r_1$

$= 0.4761 nm$

(b) $v_1 = \frac{n \hbar}{m_e r_1}$

$= \frac{6.58 \times 10^{-16} eV \cdot s}{0.511 \times 10^6 eV/c^2 \cdot 0.0529 nm}$

$= 2.17 \times 10^6 m/s$

$v_2 = 2 \cdot v_1$

$= 4.35 \times 10^6 m/s$

$v_3 = 3 \cdot v_1$

$= 6.52 \times 10^6 m/s$

(c) No those velocities are less than 10% of the speed of light.

(d) $n=3 \to n=2$: (i) $E = -13.6 eV \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

$= -1.89 eV$

(ii) $\frac{1}{\lambda} = 1.0973732 \times 10^7 m^{-1} \left(\frac{1}{4} - \frac{1}{9}\right)$

$= 1.52 \times 10^6 m^{-1}$

$\lambda = 6.56 \times 10^{-7} m$

(iii) $f = \frac{c}{\lambda}$

$= \frac{2.998 \times 10^{6}\ m/s}{6.56112 \times 10^{-7} m}$

$= 4.57 \times 10^{12}\ Hz$

(iv) $\omega_3 = \frac{v_3}{r_3}$

$= 1.37 \times 10^{16}\ Hz$

$\omega_2 = \frac{v_2}{r_2}$

$= 2.05 \times 10^{16}\ Hz$

$n=4 \rightarrow n=3$ (i) $E = -13.6\ eV\left(\frac{1}{9} - \frac{1}{16}\right)$

$= -0.661\ eV$

(ii) $\frac{1}{\lambda} = 10973732\ m^{-1}\left(\frac{1}{9} - \frac{1}{16}\right)$

$= 0.05335\ m^{-1}$

$\lambda = 18.7\ m$

(iii) $f = \frac{c}{\lambda}$

$= 159927\ Hz$

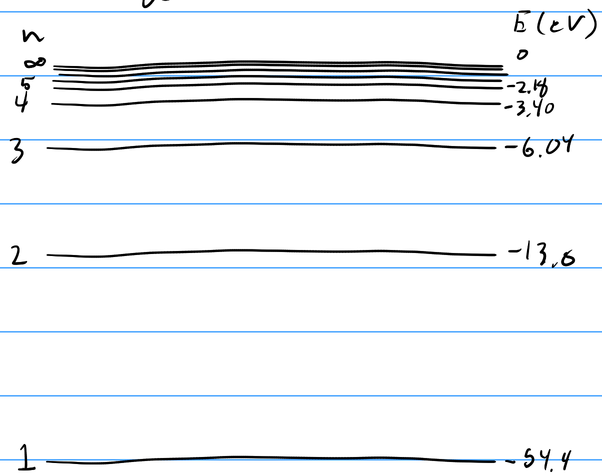
(iv) $\omega_4 = \frac{v_4}{r_4}$

$= 1.03 \times 10^{16}\ Hz$

$\omega_3 = 1.37 \times 10^{16}\ Hz$

8.

Energy levels He^+



9. $E_{ion} = -54.4\,eV$

10. $E_{2\to1} = 13.6\,eV \cdot 24^2 \left(1 - \frac{1}{4}\right)$

$K = E_{2\to1} - E_4$

$= 13.6\,eV \cdot 24^2 \left(1 - \frac{1}{4} - \frac{1}{16}\right)$

$= 5.39\,KeV$