In[1]:=
```
ClearAll["Global`*"]
```
borra todo

Funciones radiales

In[2]:=
```
R10[r_, Z_] := 2 (Z)^(3/2) Exp[-Z r];
```
exponencial

$$R21[r\_, Z\_] := \frac{1}{\text{Sqrt}[3]} \left(\frac{Z}{2}\right)^{\frac{3}{2}} (Z\, r)\, \text{Exp}\left[\frac{-Z\, r}{2}\right];$$
exponencial

$$R20[r\_, Z\_] := 2 \left(\frac{Z}{2}\right)^{\frac{3}{2}} \left(1 - \frac{Z\, r}{2}\right) \text{Exp}\left[\frac{-Z\, r}{2}\right];$$
exponencial

Integral de Coulomb

In[5]:=
```
CoulombIntegral[r1_, r2_, Z_, n_, l_] :=
  Integrate[r2^2 * If[n == 2 && l == 0, R20[r2, Z], R21[r2, Z]] *
   (Integrate[1/r2 r1^2 (R10[r1, Z])^2, {r1, 0, r2}]
    + Integrate[1/r1 r1^2 (R10[r1, Z])^2, {r1, r2, ∞}]),
   {r2, 0, ∞}];
```
integra, si, integra, integra

Integral de intercambio

In[6]:=
```
ExchangeIntegral[r1_, r2_, Z_, n_, l_] :=
 1/(2 l + 1) * Integrate[r2^2 R10[r2, Z] * If[n == 2 && l == 0, R20[r2, Z], R21[r2, Z]] *
   (Integrate[r1^2 R10[r1, Z] * If[n == 2 && l == 0, R20[r1, Z], R21[r1, Z]] (r1)^l/(r2)^(l+1),
     {r1, 0, r2}] + Integrate[
     r1^2 R10[r1, Z] * If[n == 2 && l == 0, R20[r1, Z], R21[r1, Z]] (r2)^l/(r1)^(l+1), {r1, r2, ∞}]),
  {r2, 0, ∞}]
```

Integrales para n = 2 y l = 1

In[7]:=
```
J20 = CoulombIntegral[r, ρ, 2, 2, 0]
```

Out[7]= $-\frac{1296}{625}$

In[8]:=
```
K20 = ExchangeIntegral[r, ρ, 2, 2, 0]
```

Out[8]= $\frac{32}{729}$

Integrales para n = 2 y l = 2

In[9]:=
```
J21 = CoulombIntegral[r, ρ, 2, 2, 1]
```

Out[9]= $\frac{2456}{625\sqrt{3}}$

In[10]:=
```
K21 = ExchangeIntegral[r, ρ, 2, 2, 1]
```

Out[10]= $\frac{224}{6561}$

Energía a primer orden de aproximación

Estados 2^1S y 2^3S

In[11]:=
```
FirstOrderCorrectionNL[J_, K_] := J ± K;
```

In[12]:=
```
FirstOrderCorrection20 = FirstOrderCorrectionNL[J20, K20]
```

Out[12]=
$$-\frac{1296}{625} \pm \frac{32}{729}$$

Estados 2^1P y 2^3P

In[13]:=
```
FirstOrderCorrection21 = FirstOrderCorrectionNL[J21, K21]
```

Out[13]=
$$\frac{2456}{625\sqrt{3}} \pm \frac{224}{6561}$$

Energía imperturbada

In[14]:=
```
UnperturbedEnergyN[Z_, n_] := -Z^2/2 (1 + 1/n^2);
```

In[15]:=
```
UnperturbedEnergy2 = UnperturbedEnergyN[2, 2]
```

Out[15]=
$$-\frac{5}{2}$$

Energía

Energía para estados 2^1S y 2^3S

In[16]:=
```
UnperturbedEnergy2 + FirstOrderCorrection20
```

Out[16]=
$$-\frac{5}{2} + \left(-\frac{1296}{625} \pm \frac{32}{729}\right)$$

Energía para estados 2^1P y 2^3P

In[17]:=
```
UnperturbedEnergy2 + FirstOrderCorrection21
```

Out[17]=

$$-\frac{5}{2}+\left(\frac{2456}{625\sqrt{3}}\pm\frac{224}{6561}\right)$$