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(* calculate the free gas scattering kernel *)

mn = 939.565560 × 10^6;
hbar = 6.582119 × 10^-16;
cspeed = 299 792 458;
kB = 8.617343 × 10^-5;
mA = 10;
temp = 10;
barn = 1. * 10^-28;

kn[e1_, e2_, mu_] := Sqrt[2 * mn * (e1 + e2 - 2 * mu * Sqrt[e1 * e2])] / (hbar * cspeed);
chi[t_, te_, k_] :=
  Exp[- (k * k / (2 * mA * mn)) * (kB * te * t * t / hbar - i * t) * (hbar * cspeed * cspeed)];

sigma[e1_, e2_, mu_] :=
  (1 / (4 π)) * (1 / (2 π)) * Sqrt[e2 / e1] * Integrate[Exp[-i * (e1 - e2) * t / hbar] *
    chi[t, temp, kn[e1, e2, mu]], {t, -Infinity, Infinity}];

sigmaR[e1_, e2_, k_] := (1 / (4 π)) * (1 / (2 π)) *
  Sqrt[e2 / e1] * Sqrt[2 * π * mA * mn / (temp * kB * k * k * cspeed * cspeed)] *
  Exp[- (mA * mn / (2 * kB * temp * k * k * cspeed * cspeed)) *
    ((e1 - e2) / hbar - k * k * cspeed * cspeed * hbar / (2 * mA * mn)) ^ 2];

sigmaS[e1_, e2_, mu_] := FullSimplify[sigma[e1, e2, mu]];
sigmaSS[e1_, e2_, mu_] := sigmaR[e1, e2, kn[e1, e2, mu]];
sigmaSE[e1_, e2_] := 2 * π * NIntegrate[sigmaS[e1, e2, mu], {mu, -1, 0.99}];
sigmaSSE[e1_, e2_] := 2 * π * NIntegrate[sigmaSS[e1, e2, mu], {mu, -1, 0.99}];

sigmaS[0.025, 0.0025, 0.5]
2.66708 × 10^-42 + 0. i

sigmaSE[0.025, 0.0025]

5.47994 × 10^-15 - 2.4321 × 10^-31 i

sigmaSS[0.025, 0.0025, 0.5]
2.06742 × 10^-16

sigmaSSE[0.025, 0.0025]

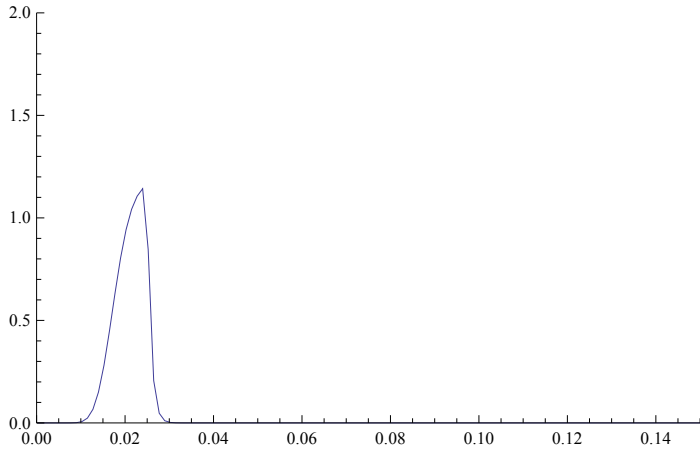
2.22198 × 10^-15

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TablXS = {};
NK = 200;
e1 = 0.00025;
e2 = 0.25;
For[j = 0, j ≤ NK, j++, AppendTo[TablXS, {e1 + j * (e2 - e1) / NK,
    sigmaSSE[0.025, e1 + j * (e2 - e1) / NK] / sigmaSSE[0.025, 0.025]}]];
ListPlot[TablXS, Joined → True, PlotRange → {{0, 0.15}, {0, 2}}]

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sigmaT[e_] := NIntegrate[
    sigmaSS[e, x, mu] / sigmaSSE[0.025, 0.025], {x, 0, Infinity}, {mu, -1, 0.99}];
TablXST = {};
NKS = 30;
For[j = 0, j ≤ NKS, j++,
    AppendTo[TablXST, {e1 + j * (e2 - e1) / NKS, sigmaT[e1 + j * (e2 - e1) / NKS]}]];
ListPlot[TablXST, Joined → True]

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