

## labs\_plots

December 18, 2025

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[116]: import numpy as np
import matplotlib.pyplot as plt
from utils.notebook_config import *
from scipy.optimize import curve_fit
```

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[117]: #Lab 2: Heat Capacity
time = [0, 30, 60, 90, 120, 150, 180, 240, 300, 260, 420, 480, 540, 600, 660, 720, 780, 840, 900, 960, 1020]
data_temp = [23.754, 23.769, 23.766, 23.760, 23.754, 23.749, 23.749, 24.238, 24.578, 24.816, 24.931, 24.986, 25.017, 25.023, 25.026, 25.023, 25.017, 25.012, 25.005, 24.996, 24.990]

def f(x, m, t):
    return m*x + t

popt1, pcov1 = curve_fit(f, time[:7], data_temp[:7])
popt2, pcov2 = curve_fit(f, time[12:], data_temp[12:])

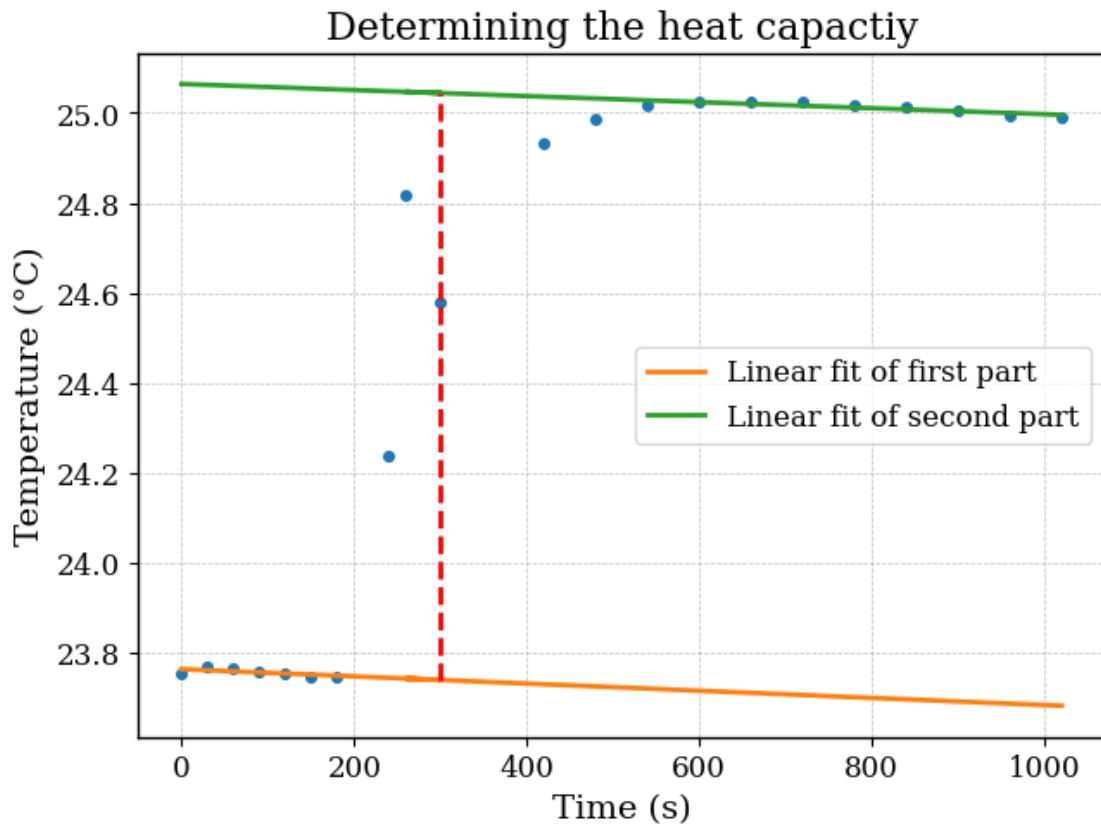
y1 = [f(i,popt1[0],popt1[1]) for i in time]
y2 = [f(i,popt2[0],popt2[1]) for i in time]

jump = 300

plt.plot(time, data_temp, marker=".", linestyle="")
plt.plot(time, y1,label="Linear fit of first part")
plt.plot(time, y2,label="Linear fit of second part")
plt.vlines(jump, f(jump, popt1[0], popt1[1]), f(jump, popt2[0], popt2[1]), linestyle="--", color="red")
plt.xlabel("Time (s)")
plt.ylabel("Temperature (°C)")
plt.legend()
plt.title("Determining the heat capacity")
plt.show()

diff = f(jump, popt2[0], popt2[1])- f(jump, popt1[0], popt1[1])
```

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print("Red line (K): ~", diff)
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Red line (K): ~ 1.3038420634925707

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[118]: #Lab 2: Ethanol
time = [0, 30, 60, 90, 180, 210, 270, 330, 390, 450, 510, 570, 630, 690, 750, 810, 870, 930, 990]
data_temp = [23.859, 23.907, 23.894, 23.890, 23.870, 23.867, 24.197, 24.675, 24.741, 24.837, 24.871, 24.889, 24.896, 24.898, 24.896, 24.892, 24.888, 24.883, 24.877]

popt1, pcov1 = curve_fit(f, time[:6], data_temp[:6])
popt2, pcov2 = curve_fit(f, time[12:], data_temp[12:])

y1 = [f(i,popt1[0],popt1[1]) for i in time]
y2 = [f(i,popt2[0],popt2[1]) for i in time]

jump = 350

plt.plot(time, data_temp, marker=".", linestyle="")
```

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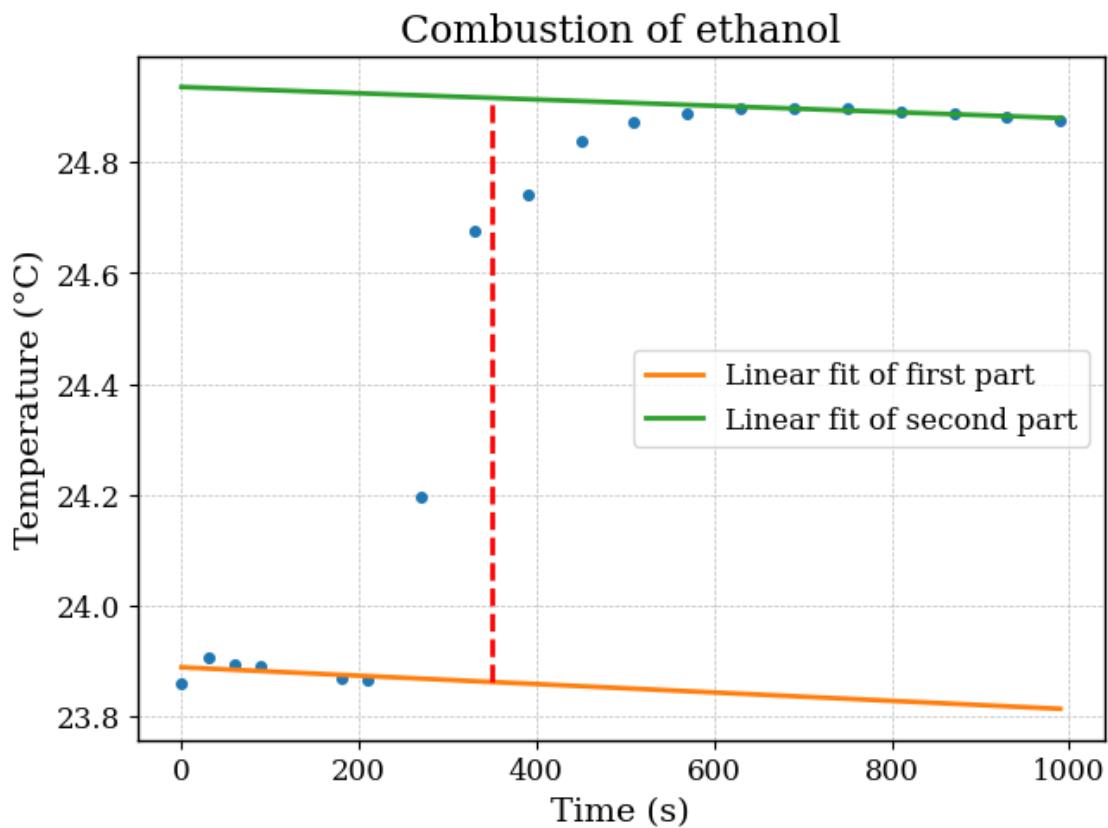
plt.plot(time, y1,label="Linear fit of first part")
plt.plot(time, y2,label="Linear fit of second part")
plt.vlines(jump, f(jump, popt1[0], popt1[1]), f(jump, popt2[0], popt2[1]),  

    ↪linestyle="--", color="red")
plt.xlabel("Time (s)")
plt.ylabel("Temperature (°C)")
plt.legend()
plt.title("Combustion of ethanol")
plt.show()

diff = f(jump, popt2[0], popt2[1])- f(jump, popt1[0], popt1[1])

print("Red line (K): ~", diff)

```



Red line (K): ~ 1.054143521356984

[119]: #Lab 2: Acetic Acid

```

time = [0, 30, 60, 90, 120, 180, 240, 300, 360, 420, 480, 540, 600, 660, 720,  

    ↪780, 840, 900]

```

```

data_temp = [22.701, 22.747, 22.731, 22.729, 22.725, 22.863, 23.200, 23.331, 23.
    ↪414, 23.449, 23.488, 23.479, 23.482, 23.483, 23.482, 23.480, 23.479, 23.474]

popt1, pcov1 = curve_fit(f, time[2:4], data_temp[2:4])
popt2, pcov2 = curve_fit(f, time[10:], data_temp[10:])

y1, y2 = [f(i,popt1[0],popt1[1]) for i in time], [f(i,popt2[0],popt2[1]) for i in
    ↪time]

jump = 300

plt.plot(time, data_temp, marker=".", linestyle="")
plt.plot(time, y1,label="Linear fit of first part")
plt.plot(time, y2,label="Linear fit of second part")
plt.vlines(jump, f(jump, popt1[0], popt1[1]), f(jump, popt2[0], popt2[1]), ↪
    ↪linestyle="--", color="red")
plt.xlabel("Time (s)")
plt.ylabel("Temperature (°C)")
plt.legend()
plt.title("Combustion of acetic acid")
plt.show()

diff = f(jump, popt2[0], popt2[1])- f(jump, popt1[0], popt1[1])

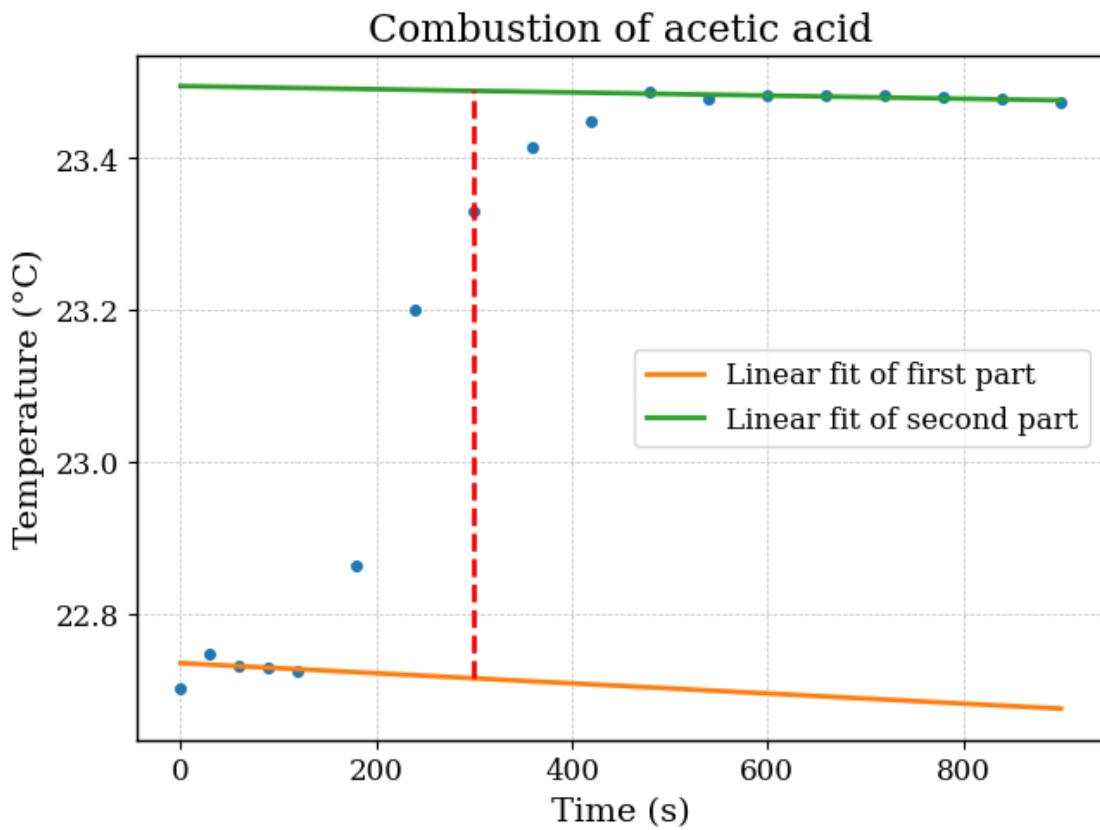
print("Red line (K): ~", diff)

```

```

/var/folders/rq/sf33k5wx73bcj8m51c786sc80000gn/T/ipykernel_75586/4215869933.py:5
: OptimizeWarning: Covariance of the parameters could not be estimated
    popt1, pcov1 = curve_fit(f, time[2:4], data_temp[2:4])

```



Red line (K): ~ 0.7739999999999583

```
[120]: #Lab 2: Ethyl Acetate
time = [0, 30, 60, 90, 120, 180, 240, 300, 360, 420, 480, 540, 600, 660, 720, 780, 840, 900]
data_temp = [23.336, 23.351, 23.341, 23.337, 23.333, 23.556, 24.078, 24.330, 24.452, 24.507, 24.533, 24.544, 24.548, 24.546, 24.543, 24.539, 24.534]

popt1, pcov1 = curve_fit(f, time[0:4], data_temp[0:4])
popt2, pcov2 = curve_fit(f, time[12:], data_temp[12:])

y1, y2 = [f(i,popt1[0],popt1[1]) for i in time], [f(i,popt2[0],popt2[1]) for i in time]

jump = 300

plt.plot(time, data_temp, marker=".", linestyle="")
plt.plot(time, y1,label="Linear fit of first part")
plt.plot(time, y2,label="Linear fit of second part")
```

```

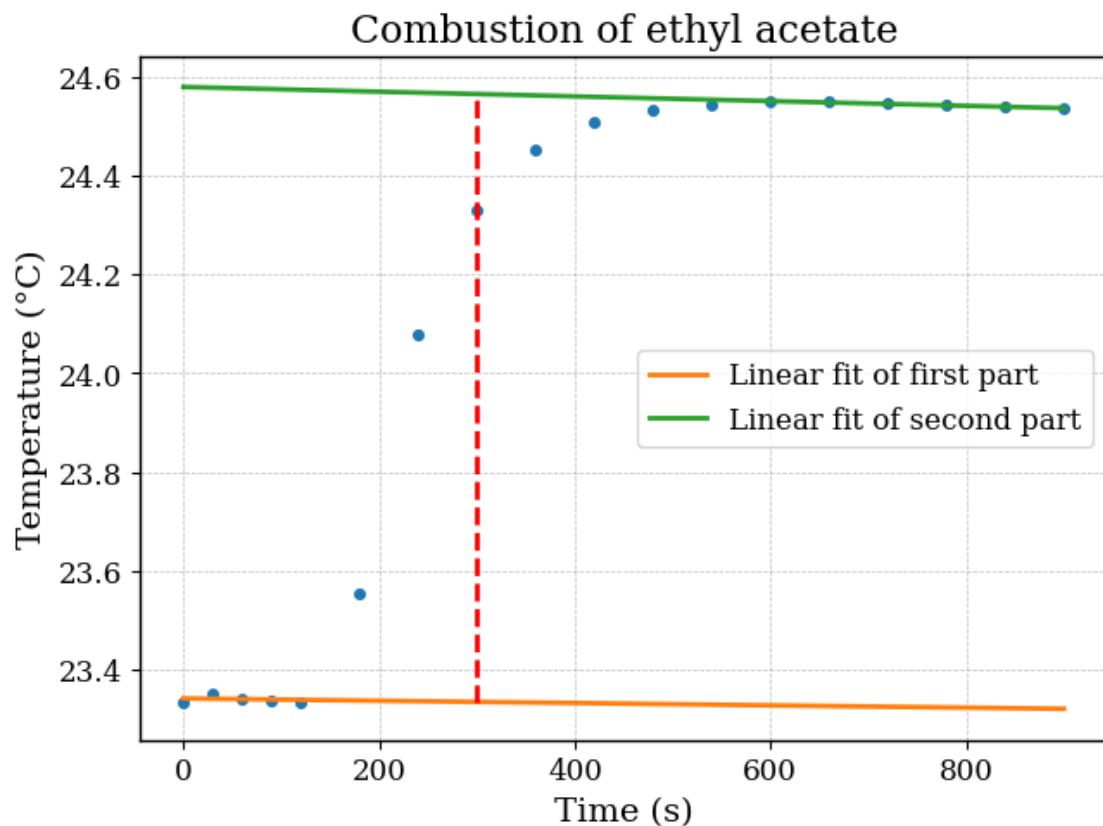
plt.vlines(jump, f(jump, popt1[0], popt1[1]), f(jump, popt2[0], popt2[1]),  

           linestyle="--", color="red")
plt.xlabel("Time (s)")
plt.ylabel("Temperature (°C)")
plt.legend()
plt.title("Combustion of ethyl acetate")
plt.show()

diff = f(jump, popt2[0], popt2[1]) - f(jump, popt1[0], popt1[1])

print("Red line (K): ~", diff)

```



Red line (K): ~ 1.2291285714283688

[121]: #Lab 4

```

vol = [0, 0.25, 0.5, 0.75, 1, 1.25, 1.5, 1.75, 2, 2.0, 2.5, 3, 3.5, 4,  

       4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 9.75, 10, 10.25, 10.5,  

       10.75, 11.25, 11.5, 11.75, 12, 12.25, 12.5, 13, 13.5, 14, 14.5,  

       15, 15.5, 16, 16.5, 17, 17.5, 18, 18.5, 19, 19.5, 20, 21, 22, 23, 24,  

       25, 26, 27, 28, 30, 31]

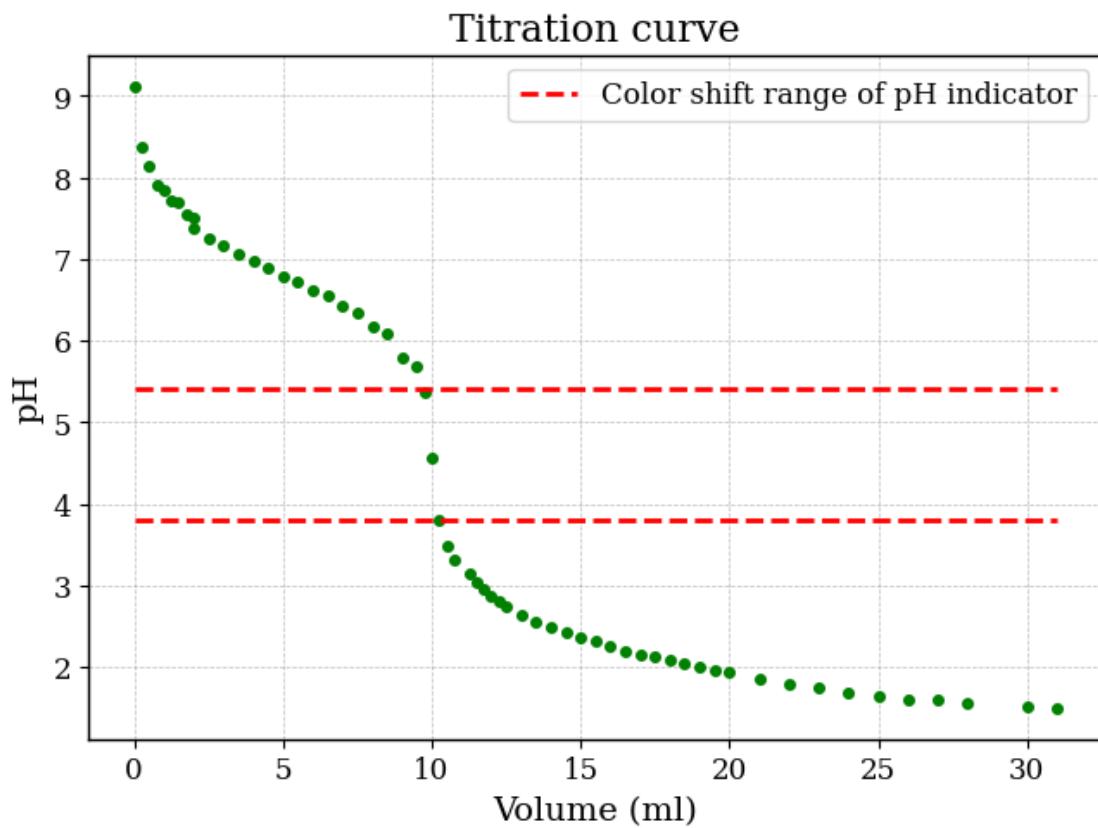
```

```

ph = [9.12, 8.37, 8.13, 7.91, 7.85, 7.71, 7.69, 7.55, 7.50, 7.37, 7.26, 7.16,
      7.07, 6.97, 6.90, 6.79, 6.72, 6.61, 6.55, 6.43, 6.33, 6.18, 6.08, 5.79,
      5.68, 5.36, 4.57, 3.80, 3.49, 3.31, 3.15, 3.04, 2.95, 2.87, 2.80, 2.75,
      2.64, 2.56, 2.49, 2.42, 2.37, 2.31, 2.26, 2.20, 2.16, 2.12, 2.08, 2.04,
      2.01, 1.96, 1.94, 1.85, 1.79, 1.75, 1.68, 1.65, 1.61, 1.59, 1.56, 1.52, 1.
      ↵50]

plt.plot(vol, ph, linestyle="", marker=".", color="green")
plt.xlabel("Volume (ml)")
plt.hlines(3.8, 0, 31, linestyle="--", color="red")
plt.hlines(5.4, 0, 31, linestyle="--", color="red", label="Color shift range\u2192
      ↵of pH indicator")
plt.ylabel("pH")
plt.legend()
plt.title("Titration curve")
plt.show()

```



[122]: #Lab 5

```

time = [0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330, 360, 390, 420, 450]

abs1 = [1.4163, 1.3655, 1.3176, 1.2706, 1.2258, 1.1818, 1.1389, 1.0976, 1.0580, 1.0191, 0.9823, 0.9464, 0.9123, 0.8791, 0.8476, 0.8166]
abs2 = [1.2255, 1.1477, 1.0609, 0.9775, 0.9035, 0.8365, 0.7755, 0.7197, 0.6681, 0.6201, 0.5738, 0.5260, 0.4790, 0.4312, 0.3961, 0.3665]
abs3 = [1.1723, 1.0420, 0.9345, 0.8092, 0.6895, 0.6017, 0.5206, 0.4384, 0.3739, 0.3225, 0.2781, 0.2363, 0.1995, 0.1723, 0.1527, 0.1379]

popt1, pcov1 = curve_fit(f, time, abs1)
popt2, pcov2 = curve_fit(f, time, abs2)
popt3, pcov3 = curve_fit(f, time, abs3)

y1, y2, y3 = [f(i,popt1[0],popt1[1]) for i in time], [f(i,popt2[0],popt2[1]) for i in time], [f(i,popt3[0],popt3[1]) for i in time]

plt.plot(time, abs1, linestyle="", marker=". ", label="293 K")
plt.plot(time, abs2, linestyle="", marker=". ", label="303 K")
plt.plot(time, abs3, linestyle="", marker=". ", label="313 K")

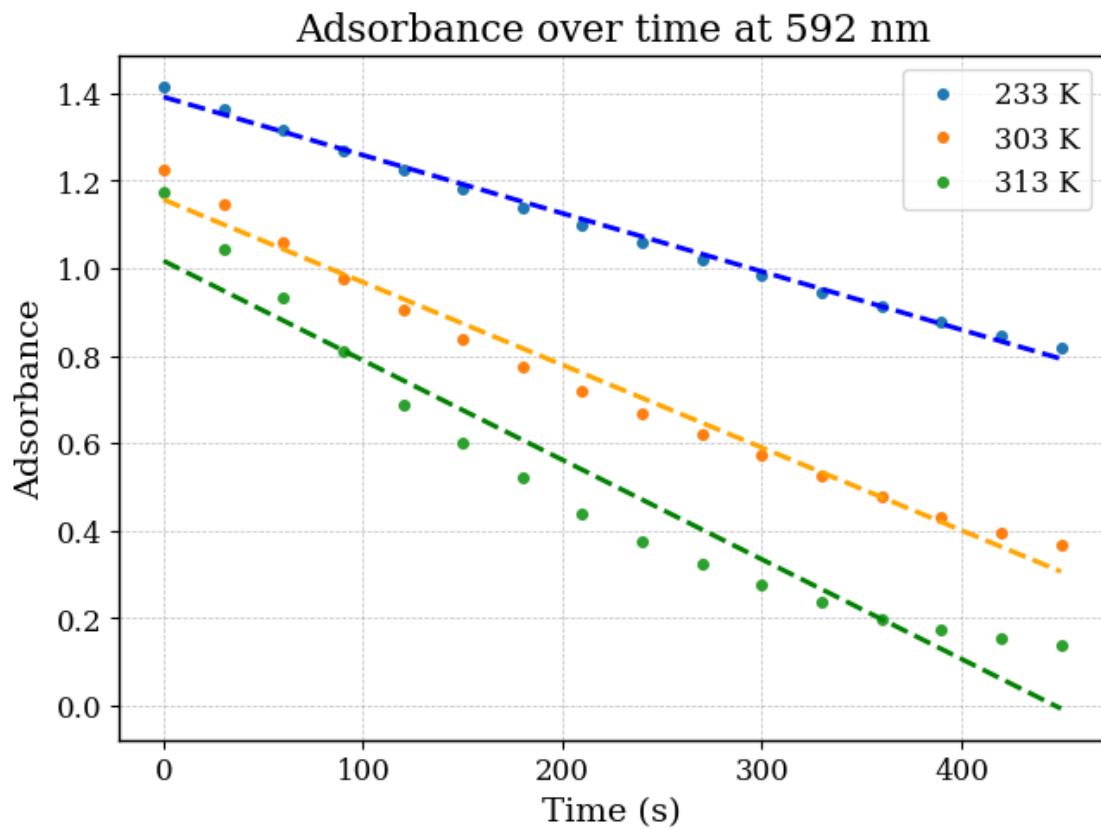
plt.plot(time, y1, color="blue", linestyle="--"), plt.plot(time, y2, color="orange", linestyle="--")
plt.plot(time, y3, color="green", linestyle="--")

plt.xlabel("Time (s)")
plt.ylabel("Adsorbance")
plt.title("Adsorbance over time at 592 nm")

plt.legend()
plt.show()

print("293 K: k = ", popt1[0])
print("303 K: k = ", popt2[0])
print("313 K: k = ", popt3[0])

```



293 K:  $k = -0.0013298382352942006$

303 K:  $k = -0.0018893529411765364$

313 K:  $k = -0.002274392156862648$