Question 8.1

$$E^{'} = k_3ES + k_2ES - k_1E \times S$$

$$S^{'} = k_2ES - k_1E \times S$$

$$ES^{'} = k_1E \times S - k_2ES - k_3ES$$

$$P^{'} = k_3ES$$

Qesution 8.2

```
import numpy as np
import matplotlib.pyplot as plt
```

```
def ESP(y,  Kp):
    E=y[0]
    S=y[1]
    ES=y[2]
    P=y[3]
    Ea=Kp[2]*ES+Kp[1]*ES-Kp[0]*E*S
    Sa=Kp[1]*ES-Kp[0]*E*S
    ESa=Kp[0]*E*S-Kp[1]*ES-Kp[2]*ES
    Pa=Kp[2]*ES
    res=np.array([Ea,Sa,ESa,Pa])
    return res
```

```
def RK4(y0,dt,Nt):# E ,S ,ES ,P
    y=np.zeros((y0.shape[0],Nt),dtype=np.float)
    y[:,0]=y0
    Kp=[100,600,150]
    for i in range(0,Nt-1):
        a1=ESP(y[:,i],Kp)
        a2=ESP(y[:,i]+a1*dt/2,Kp)
        a3=ESP(y[:,i]+a2*dt/2,Kp)
        a4=ESP(y[:,i]+a3*dt,Kp)
        y[:,i+1]=y[:,i]+dt/6*(a1+2*a2+2*a3+a4)
    return y
```

```
init=[1,10,0,0]
init=np.array(init)
```

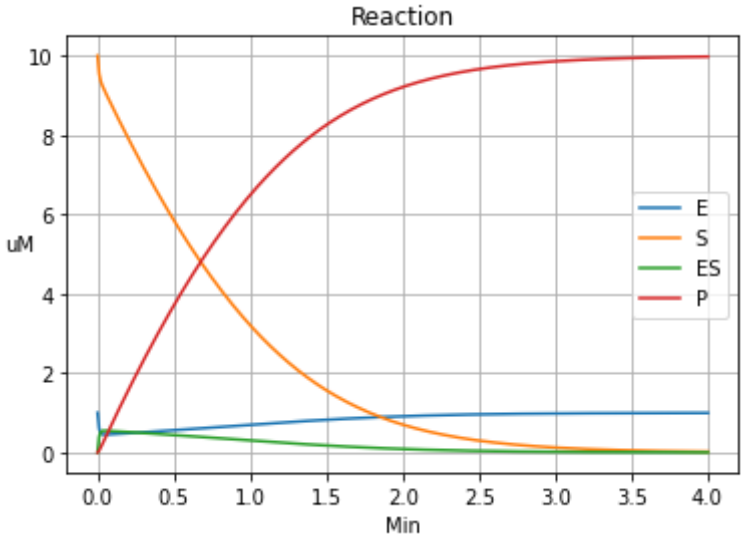
```
dt=0.001
times=400
```

```
res=RK4(init,dt,times)
```

```
x=np.linspace(0,4,400)
```

```
plt.plot(x,res[0,:],label='E')
plt.plot(x,res[1,:],label='S')
plt.plot(x,res[2,:],label='ES')
plt.plot(x,res[3,:],label='P')

plt.title('Reaction')
plt.grid()
plt.ylabel('uM',rotation=0)
plt.xlabel('Min')
plt.legend()
plt.show()
```




```

```

```

```

Question 8.3

```
init=[1,10,0,0]
init=np.array(init)
dt=0.001
times=400
```

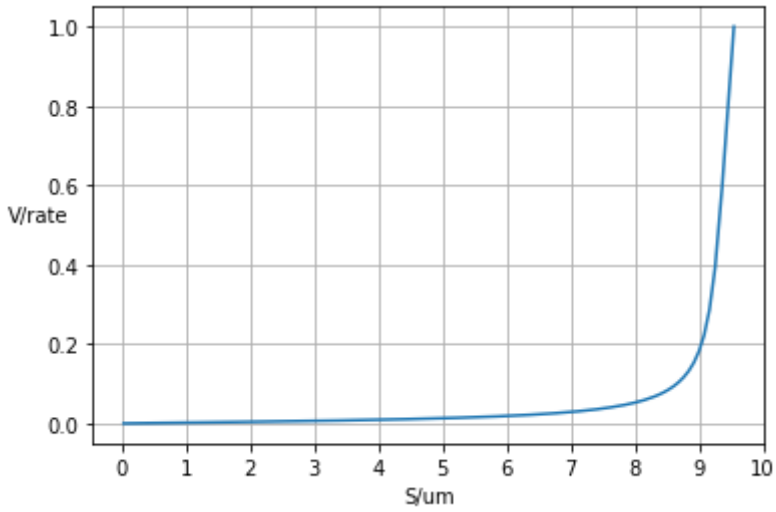
```
res=RK4(init,dt,times)
```

Calculates it's left derivative because Np start with 0.

```
Np= res[3,:]
Vp=np.zeros((Np.shape[0]-1),dtype=np.float)
for i in range(0,Np.shape[0]-1):
    Vp[i]=(Np[i+1]-Np[i])/Np[i+1]
```

```
plt.xticks(np.arange(0,11,1))
plt.xlabel('S/um')
plt.ylabel('V/rate',rotation=0)
plt.grid()
plt.plot(res[1,1:],Vp)
```

```
[<matplotlib.lines.Line2D at 0x118dca49dc8>]
```

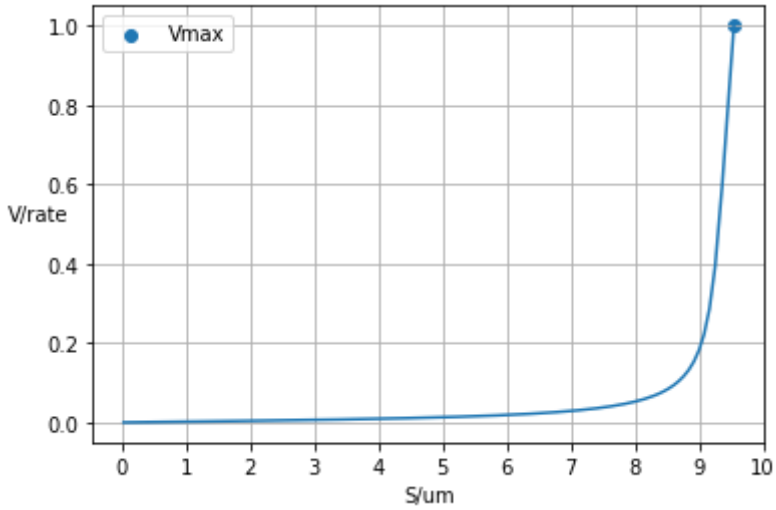



```
max=0
index=0
for i in range(0,399):
    if max<Vp[i]:
        max=Vp[i]
        index=i
print(max,res[1,index+1])
```

```
1.0 9.54701001764323
```

```
plt.xticks(np.arange(0,11,1))
plt.xlabel('S/um')
plt.ylabel('V/rate',rotation=0)
plt.grid()
plt.scatter(res[1,index+1],max,label='Vmax')
plt.legend()
plt.plot(res[1,1:],Vp)
```

```
[<matplotlib.lines.Line2D at 0x118dcace088>]
```



reference

[1]李汝雄. 化学反应动力学微分方程组中线性参数的代数估计方法[J]. 武汉工程大学学报, 1990, 012(001):63-67.

[2]https://zhuanlan.zhihu.com/p/34261490