Isotherms of Real Gases - W12e

```
md""" # Isotherms of Real Gases - W12e
"""
```

```
begin
    using Pkg
    using LsqFit
    using CSV
    using PlutoUI
    using Plots
    using LsqFit
    import Pkg; Pkg.add("ORCA")
    using ORCA
    plotly()
    theme(:bright)
end
```

Importing Experimental Data Bellow

	Volume (ml)	Pressure (bar) 10	Pressure (bar) 15	Pressure (bar) 20	Pressure (bar) 25	Pressure (bar) 30	Pressure (bar) 35	Pressure (bar) 40	Pres (bai
1	4.0	7.5	7.5	7.82	8.0	8.0	8.43	8.5	8.5
2	3.9	7.63	7.5	8.0	8.0	8.29	8.5	8.5	8.91
3	3.8	8.0	8.0	8.0	8.37	8.5	8.79	8.98	9.0
4	3.7	8.38	8.35	8.3	8.5	8.99	9.0	9.0	9.48
5	3.6	8.5	8.5	8.5	8.5	9.0	9.39	9.5	9.5
6	3.5	8.79	8.5	8.79	9.0	9.35	9.5	9.95	10.0
7	3.4	9.0	8.86	9.0	9.42	9.5	9.98	10.0	10.0
8	3.3	9.32	9.0	9.48	9.5	9.92	10.0	10.3	10.5
9	3.2	9.5	9.32	9.5	10.0	10.0	10.32	10.5	10.8
10	3.1	9.91	9.87	10.0	10.0	10.5	10.93	11.0	11.0

: more

```
begin
    csv_file=CSV.File("P_Data.csv")
    data_balls=DataFrame(csv_file)
end
```

1.

Measuring the isotherms of a substance for eight temperatures.

```
md"""
#### 1.
###### Measuring the isotherms of a substance for eight temperatures.

"""
```

As the pressure is Close to the critical point, the substance is a mix of solid and liquid states. As a plot projection, this can be seen as the sudden flattening of the slopes in the Figure below, i.e constant pressure value for a changing volume. This flattening of the curve or the width, ΔV, of the flat slope gets smaller and smaller as the temperature is increased.

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and liquid states. As a plot projection, this can be seen as the sudden flattening of
the slopes in the Figure below, i.e constant pressure value for a changing volume.
This flattening of the curve or the width, ΔV, of the flat slope gets smaller and
smaller as the temperature is increased.
"""
```

```
▸Float64[1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0]
```

```
▸Union{Missing, Float64}[9.0, 9.49, 9.5, 9.94, 10.0, 10.43, 10.5, 11.0, 11.42, 11.5,
```

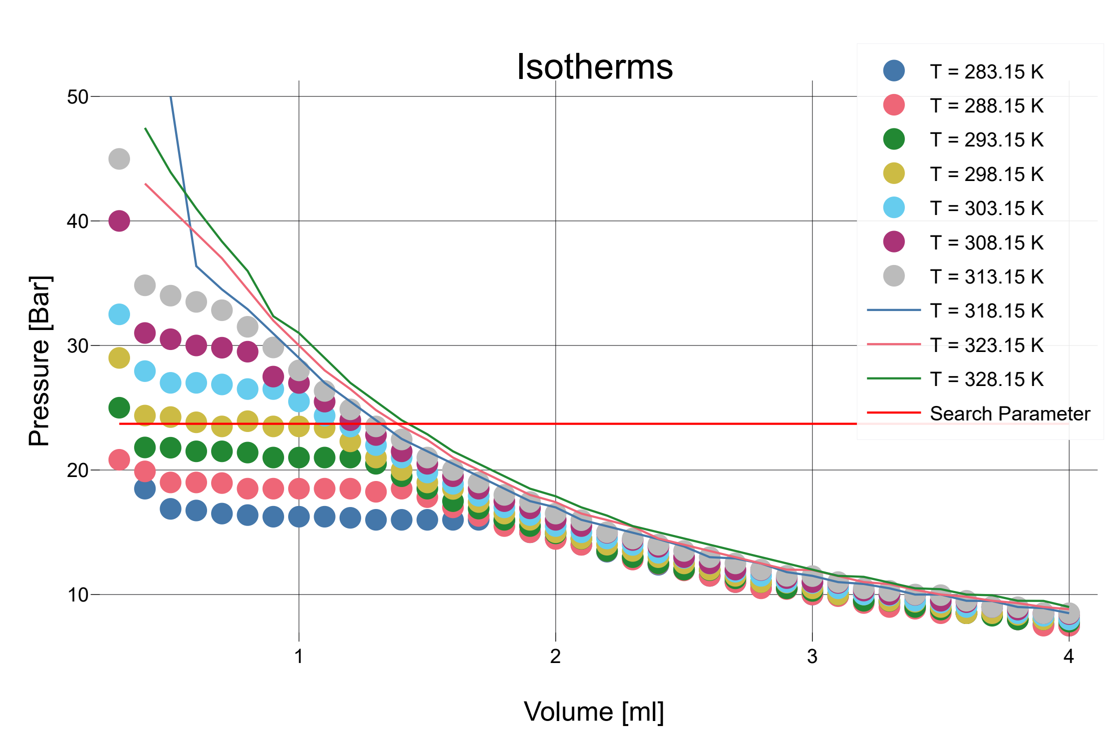
2.

Plotting isotherms and determining the saturation vapour pressure p_{s} in the region of Maxwell line.

```
md"""
#### 2.
###### Plotting isotherms and determining the saturation vapour pressure $p_{s}$ in
the region of Maxwell line.
"""
```

Slider to fetch the data at palce of intrest on the graph

23.71




```
begin
    scatter(volume, p10,label="T = 283.15 K", size(1000,1000),xlabel="Volume
[ml]",ylabel="Pressure [Bar]",title="Isotherms")
    scatter!(volume, p15,label ="T = 288.15 K")
    scatter!(volume, p20,label ="T = 293.15 K")
    scatter!(volume, p25,label ="T = 298.15 K")
    scatter!(volume, p30,label ="T = 303.15 K")
    scatter!(volume, p35,label ="T = 308.15 K")
    scatter!(volume, p40,label ="T = 313.15 K")
    plot!(volume, p45,label ="T = 318.15 K")
    plot!(volume, p50,label ="T = 323.15 K")
    plot!(volume, p55,label ="T = 328.15 K")
    plot!(volume, ones(length(volume))*i, label="Search Parameter",color="red")
end
```

Above is the plot of pressure against volume measurements of all the given temperatures. It can be seen that the flattened slopes are not a straight line along the x-axis and have a slight tilt along the y-axis. For this reason, a slider is coded in to find the areas of interest within a particular temperature plot. Once we determined the start and finish of a flattened slope for a particular temperature, we take the average of the corresponding y-axis values, i.e presure value.

Below is the table of final obtained values of saturation pressure to the corresponding temperature.

Temperature [°C]	T=10	T=15	T=20	T=25	T=30	T=35	T=40	T=45	T=50	T=5!
Average saturation pressure(P_s)[Bar]	16.342	18.525	21.25	23.783	26.774	30.164	33.332	36.37	N.A	N.A

```
md"
| Temperature [°C]|T=10|T= 15|T=20|T=25|T=30|T=35|T=40|T=45|T=50|T=55|
|:---------- | ---------- |:------------:|:------------:|:------------:|:-----------
-:|:------------:|:------------:|:------------:|:------------:|:------------:|
| Average saturation pressure( $P_{s}$)[Bar]
|16.342|18.525|21.25|23.783|26.774|30.164|33.332|36.37|N.A|N.A|"
```

```
Enter cell code...
```

16.342

```
pp[1]=sum(p10[27:36])/length(p10[27:36]) #takes the average of these values
```

18.525

```
pp[2]=sum(p15[length(p15)-11:length(p15)-4])/length(p15[length(p15)-11:length(p15)-4]
)
```

21.25

```
pp[3]=sum(p20[length(p20)-10:length(p20)-1])/length(p20[length(p20)-10:length(p20)-1]
)
```

23.78375

```
pp[4]=sum(p25[length(p25)-8:length(p25)-1])/length(p25[length(p25)-8:length(p25)-1])
```

26.774

```
pp[5]=sum(p30[length(p30)-6:length(p30)-2])/length(p30[length(p30)-6:length(p30)-2])
```

30.163999999999998

```
pp[6]=sum(p35[length(p35)-5:length(p35)-1])/length(p35[length(p35)-5:length(p35)-1])
```

33.331999999999994

```
pp[7]=sum(p40[length(p40)-5:length(p40)-1])/length(p40[length(p40)-5:length(p40)-1])
```

T = ▸Float64[283.15, 288.15, 293.15, 298.15, 303.15, 308.15, 313.15]

```
T=[283.15,288.15,293.15,298.15,303.15,308.15,313.15]
```

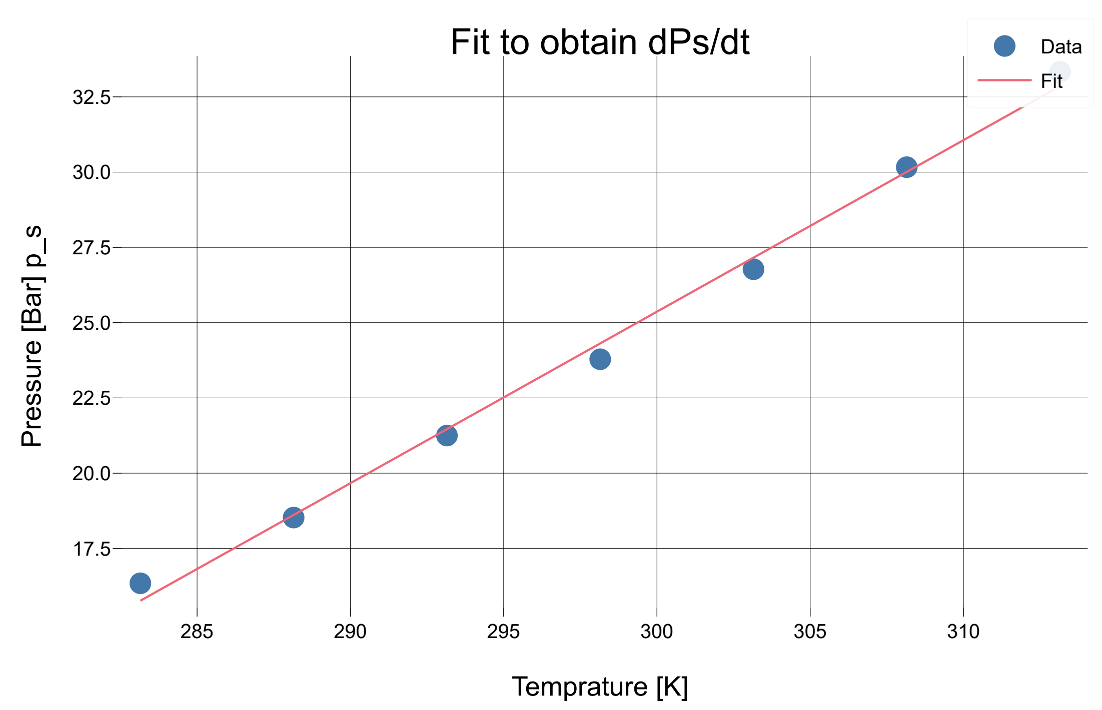
3.

Plotting $ln(p_s)$ as function of "1/T". Fitting this plot with the vapour pressure equation to determine the average molar latent heat of vaporization of the substance under study i.e Q_{23}

```
md"""
#### 3.
###### Plotting $ln(p_{s})$ as function of "1/T". Fitting this plot with the vapour
pressure equation to determine the average molar latent heat of vaporization of the
substance under study i.e $Q_{23}$
"""
```

▸LsqFit.LsqFitResult{Array{Float64,1},Array{Float64,1},Array{Float64,2},Array{Float64,1}}(

```
begin
    @. linefittwo(c,stuff)=stuff[1]*c + stuff[2]
    ran2=[1.2,1.0]
    fit2= curve_fit(linefittwo, T, pp,ran2)
end
```

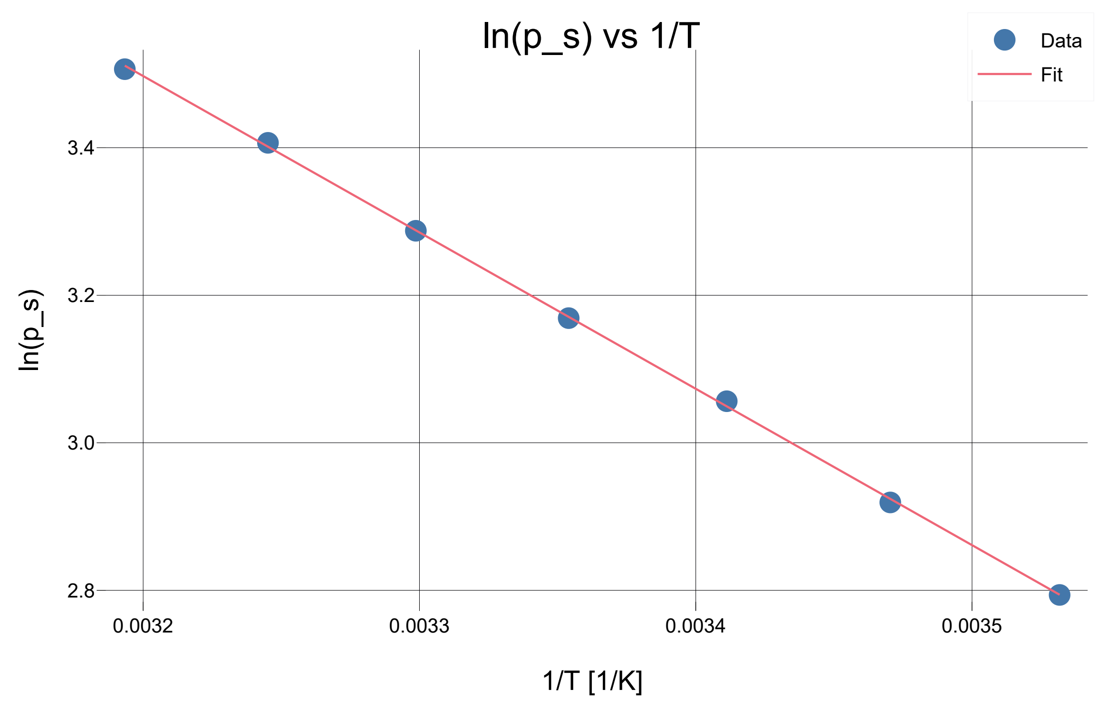


dpdt = 0.569800000034192

```
dpdt = fit2.param[1]
```

▸LsqFit.LsqFitResult{Array{Float64,1},Array{Float64,1},Array{Float64,2},Array{Float64,1}}(

```
begin
    @. linefit(c,stuff)=stuff[1]*c + stuff[2]
    ran=[1.2,1.0]
    fit1= curve_fit(linefit, (1 ./T), log.(pp),ran)
end
```




```
begin
    scatter((1 ./T),log.(pp),xlabel="1/T
[1/K]",ylabel="ln(p_s)",label="Data",title="ln(p_s) vs 1/T")
    plot!((1 ./T), linefit((1 ./T),fit1.param),label="Fit")
end
```

```
Slope = -2119.7918237326458
```

$$ln(p_s) = \frac{Q_{23}}{R} \cdot \frac{1}{T} + ln(p_{s0})$$

Using the above formula Q_{23} can be equated with the slope of the fit

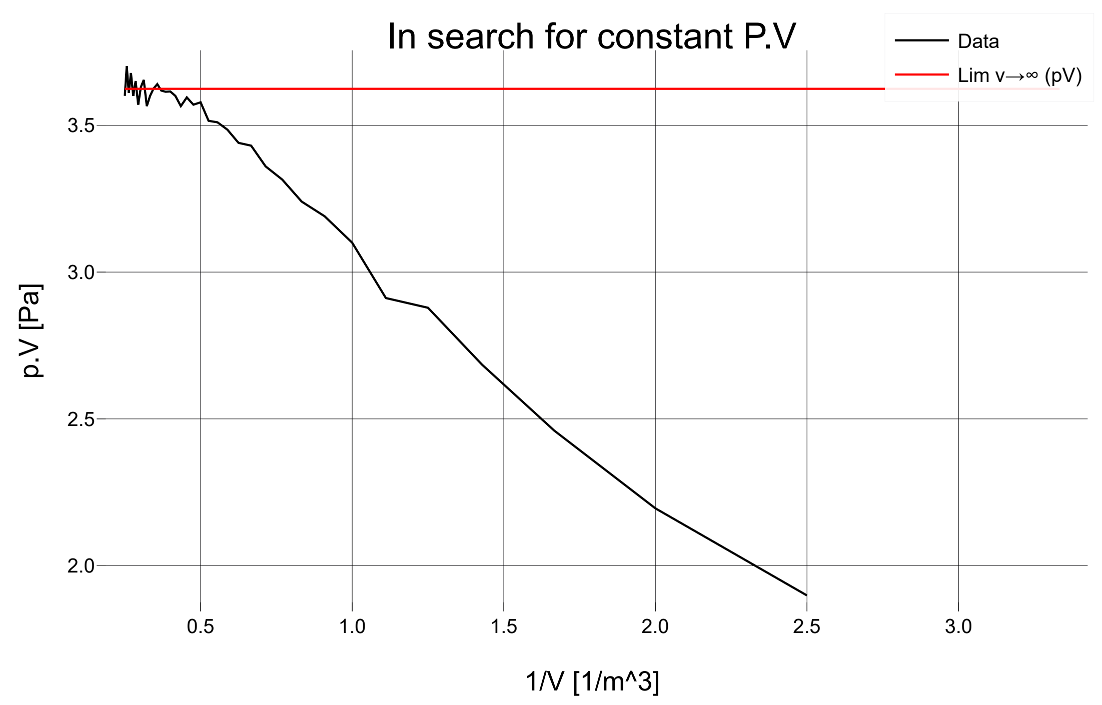
The Calculated value $Q_{23} = (1.7236 \pm 0.01) \cdot \frac{J}{mol}$

4.

Determining the amount of the substance under study.

3.624

```
@bind j Slider(0.0:0.001:3.9, show_value=true) #3.624
```



Interpreting from the equation $lim_{v \to \infty}(p.V) = nRT$, we particularly look for a region where the P.V value approximately stabilizes around a constant value, i.e value of P.V when $V \to \infty$.

Further using $n = \frac{p.V}{RT}$

we obtain the calulated value of $n = (1537 \pm 5) \cdot 10^{-6} mol$

5.

Use the Clausius-Clapeyron equation to determine the molar heat of vaporization as a function of temperature. Plot the latent heat as a function of the reduced temperature $\frac{T}{T_K}$ and make a power fit on the data.

$$Q_{23}(T) = \frac{dp_s}{dT} \cdot T \frac{\Delta V_m}{n} [1]$$

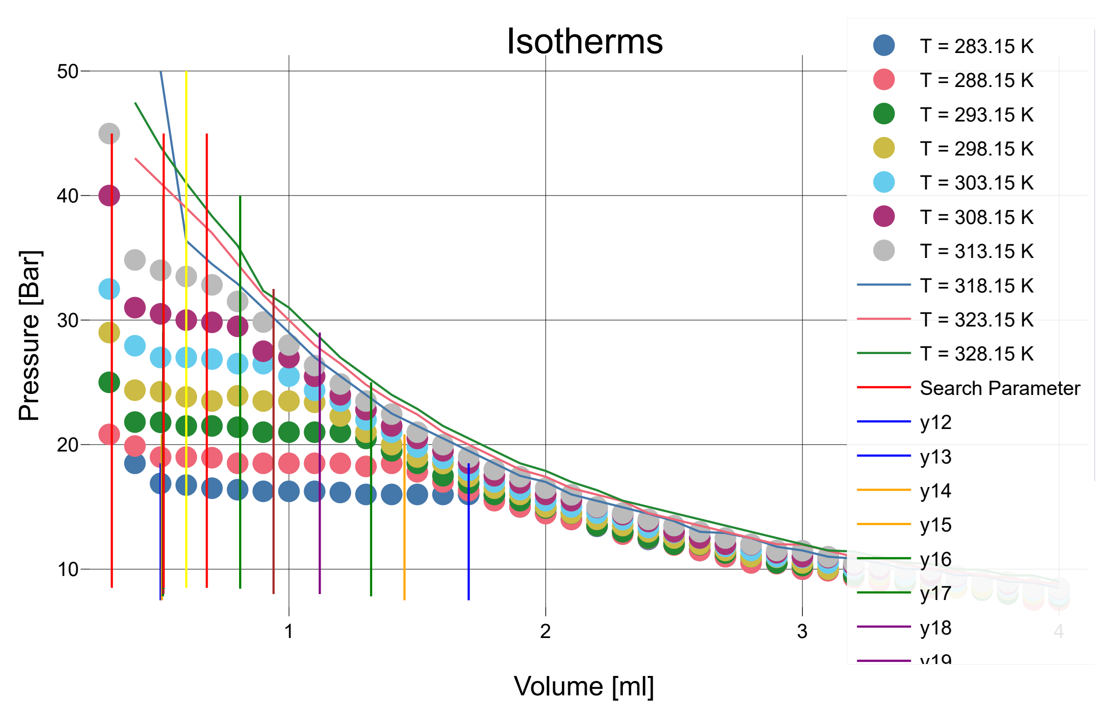
$$as. \Delta V = V_g - V_l$$

$$and. \frac{dp_s}{dT} = p_{s0} \cdot \frac{Q_{23}}{RT_2} \cdot e^{-Q_{23}/RT}$$

$$\Delta V_m = \frac{V_g - V_l}{n}$$

we can use Equation [1] to plot Q_23 as a function of 'T'. To get further we also need to find the values of ΔV, this is done using the graph below. Using the slider different region of interest is examined; After the values around are searched for the best results and line is plotted as a reference.

0.31




```
begin
    scatter(volume, p10,label="T = 283.15 K", size(1000,1000),xlabel="Volume
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    scatter!(volume, p15,label ="T = 288.15 K")
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```

```
    scatter!(volume, p25,label ="T = 298.15 K")
    scatter!(volume, p30,label ="T = 303.15 K")
    scatter!(volume, p35,label ="T = 308.15 K")
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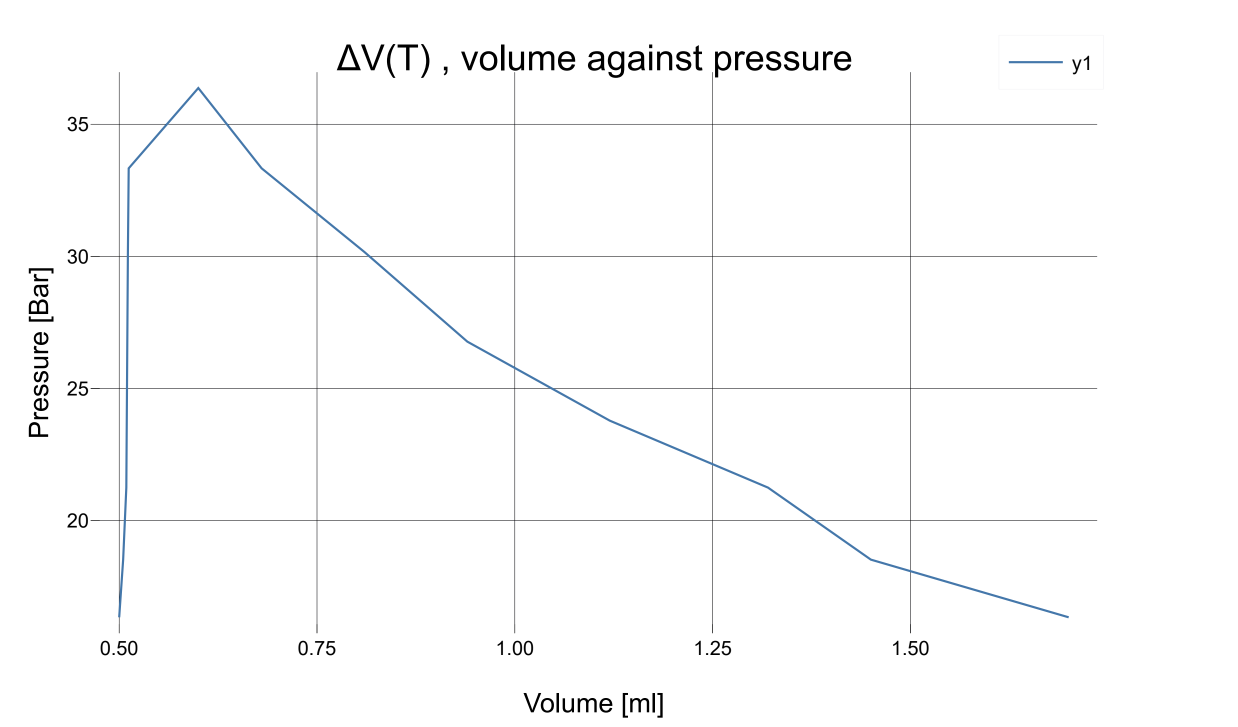
    plot!(volume, p45,label ="T = 318.15 K")
    plot!(volume, p50,label ="T = 323.15 K")
    plot!(volume, p55,label ="T = 328.15 K")
    plot!(ones(length(volume))*o, p40, label="Search Parameter",color="red")
    plot!(ones(length(volume))*0.5,p10,color="blue")
    plot!(ones(length(volume))*1.7,p10,color="blue")
    plot!(ones(length(volume))*0.505,p15,color="orange")
    plot!(ones(length(volume))*1.45,p15,color="orange")
    plot!(ones(length(volume))*0.509,p20,color="green")
    plot!(ones(length(volume))*1.32,p20,color="green")
    plot!(ones(length(volume))*0.51,p25,color="purple")
    plot!(ones(length(volume))*1.12,p25,color="purple")
    plot!(ones(length(volume))*0.511,p30,color="brown")
    plot!(ones(length(volume))*0.94,p30,color="brown")
    plot!(ones(length(volume))*0.511,p35,color="green")
    plot!(ones(length(volume))*0.81,p35,color="green")
    plot!(ones(length(volume))*0.512,p40,color="red")
    plot!(ones(length(volume))*0.68,p40,color="red")
    plot!(ones(length(volume))*0.6,p45,color="yellow")
end
```

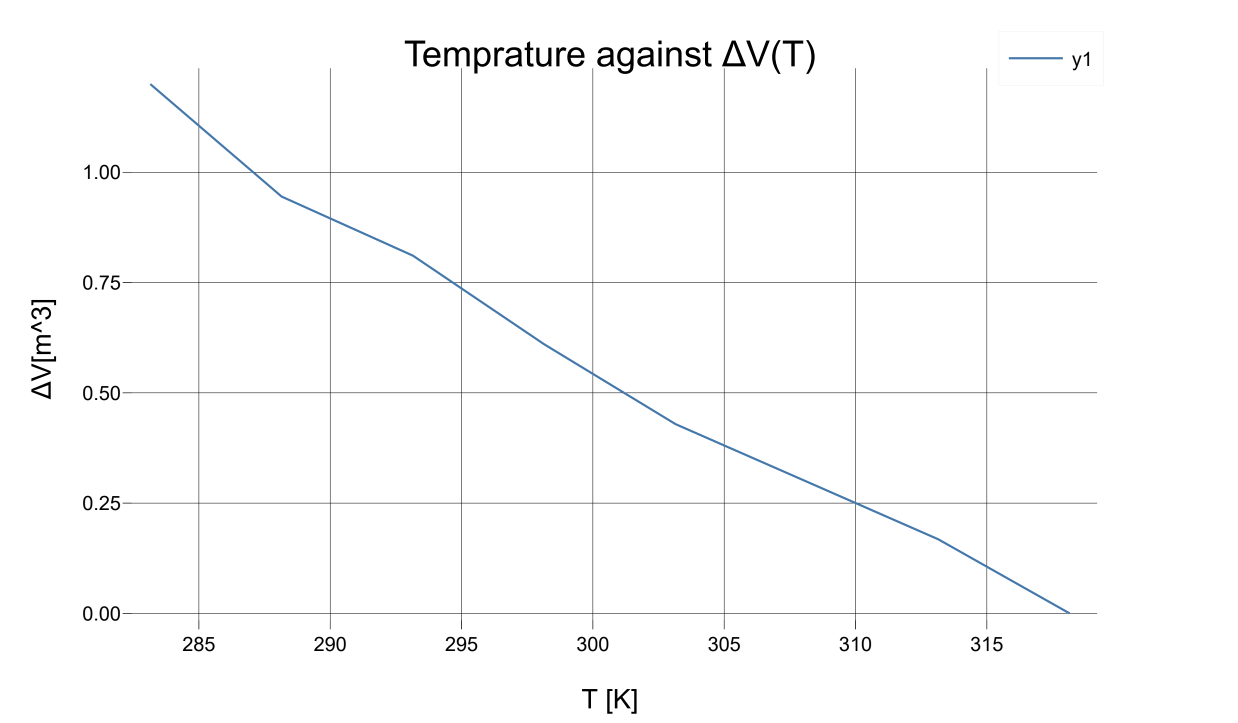
```
newp =
▸Float64[16.342,  18.525,  21.25,  23.7838,  26.774,  30.164,  33.332,  36.37,  33.332,  30.1
```

```
ΔV = ▸Float64[1.2,  0.945,  0.811,  0.61,  0.429,  0.299,  0.168,  0.0]
```

```
newv =
▸Float64[0.5,  0.505,  0.509,  0.51,  0.511,  0.511,  0.512,  0.6,  0.68,  0.81,  0.94,  1.12
```




```
plot(newv, newp,title="ΔV(T) , volume against pressure",xlabel="Volume
[ml]",ylabel="Pressure [Bar]")
```



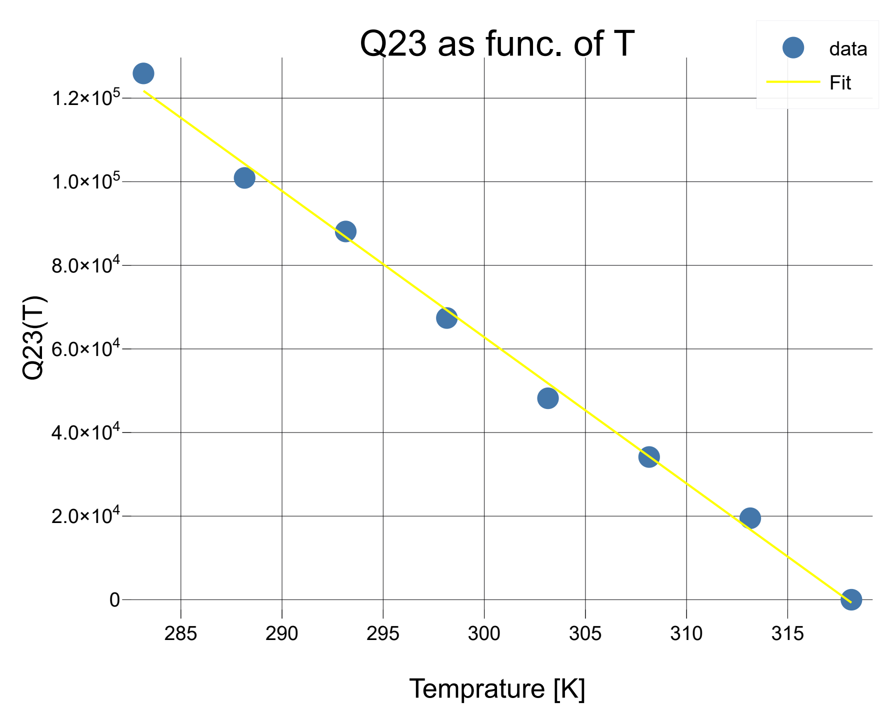

```
begin
    T2=[T; 318.15]
    plot(T2,ΔV,title="Temprature against ΔV(T)",xlabel="T [K]", ylabel="ΔV[m^3]")
end
```

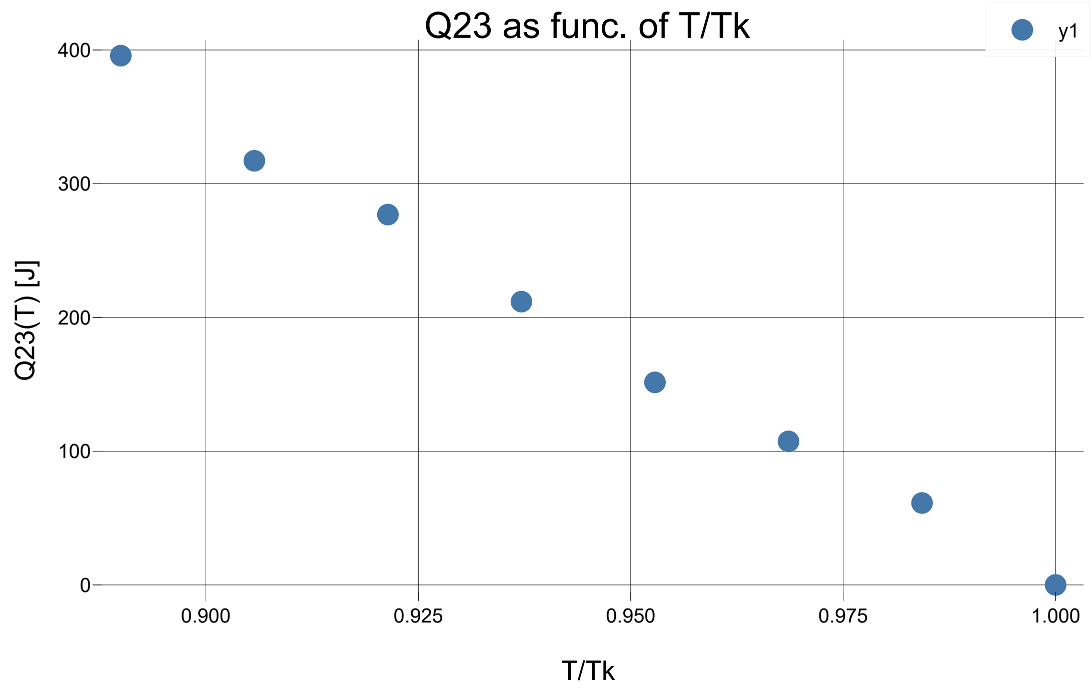
```
Q23 (generic function with 1 method)
```

```
▸LsqFit.LsqFitResult{Array{Float64,1},Array{Float64,1},Array{Float64,2},Array{Float64,1}}(
```

```
▸LsqFit.LsqFitResult{Array{Float64,1},Array{Float64,1},Array{Float64,2},Array{Float64,1}}(
```

Though the Q-{23} is defined as $Q_{23}(T) = \frac{dp_s}{dT} \cdot T \frac{\Delta V_m}{n}[1]$ we use the equation below to make power fit to the graph below $Q - 23 = Q_{23}(0) \cdot (1 - \frac{T}{T_k})^{3/8}$




Q23 as func. of T/Tk
y1
400
300
200
100
0
Q23(T) [J]
0.900
0.925
0.950
0.975
1.000
T/Tk