Liquid – Vapor Saturation Curve

University of Jordan

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★ Objectives:

To show that pressure and temperature are dependent properties in saturation region, then draw that relation between them, after comparing theoretical values with values taken in lab.

★ Introduction & Theory

The saturation curve of liquid - vapor is a critical notion in thermodynamics and phase equilibrium. It illustrates the temperature and pressure point at which a substance changes from its vapor to liquid phases and vice versa while still remaining in an equilibrium state. As such, the curve is a vital illustration in various disciplines, wholesale and retail, including chemical engineering, meteorology, and chemistry, offering insights into boiling and condensing processes and natural occurrences such as ENGO cloud formation. Learning the particular behavior that is depicted by the saturation curve is critical to maintaining industrial procedures growing accurate weather forecasting and understanding the influence of temperature and pressure on diverse systems.

In this experiment it's worth mentioning the idea of *Thermal Hysteresis* which is the difference between the melting and freezing temperatures of a particular composite, as demonstrated by the behavior of pure water. Water freezes very close to 0°C but can supercool very large (about −42°C) in

bulk, far more on surfaces, in the absence of effective nucleators. With nucleators present, the melting and freezing points are effectively identical, which implies there is no inherent thermal hysteresis. Therefore, thermal hysteresis describes how the thermal past of a composite influences it, as represented by the sweetness and temperature of ice. Warming or cooling to these temperatures will, in the end, have different influences depending on one's past behavior rather than just the present temperature.

In this experiment we need to show that

$$\frac{(\mathrm{dT})}{(dP)_{sat}} = \frac{T v_{fg}}{h_{fg}}$$

Where:

$V_{fg} = V_g - V_f$

V_g = Specific volume of saturated vapor. (m^3/kg)
V_f = Specific volume of saturated liquid. (m^3/kg)

$h_{fg} = h_g - h_f$ (kJ/kg)

h_g = Specific enthalpy of saturated vapor. (kJ/kg)
h_f = Specific enthalpy of saturated liquid. (kJ/kg)
T = Absolute Temperature (K).

$\frac{(dT)}{(dP)_{sat}}$ which is the slope of pressure – temperature curve for saturated steam in equilibrium with saturated liquid.

Known as Clausis-Claperon Equation.

★ Apparatus&Equipment

Marcet Boiler: It consists of a small cylindrical boiler fitted with a thermometer and a pressure gauge.

★ Procedure

Starting the Experiment

1. Open the level tap at the side of the boiler, and remove the filler plug.

2. Fill the boiler with clean water through the filler plug until it reaches the level of the tap.

3. Replace the filler plug and tighten (Leave tap open so that air

can escape during heating).

4. Insert thermometer into the hole in filler plug.

5. Place beaker directly under the level tap.

6. Plug unit into wall socket.

7. Wait until water is boiling then close level tap, which should take about 12 mins.

8. As pressure rises take simultaneous readings of pressure and temperature at pressure intervals of one bar, to a maximum pressure of two bars.

9. Unplug unit from wall socket and as the pressure drops take simultaneous readings of pressure and temperature at intervals of one bar until the pressure-gauge readings reduce to zero.

★Data collection

Barometric Pressure = 90 kPa = 0.9 bar.

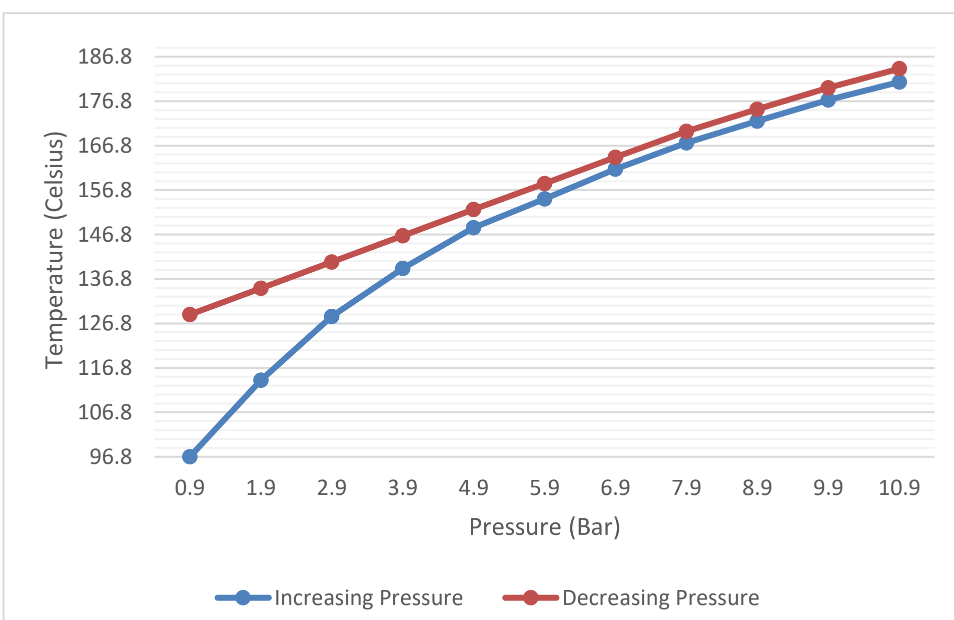
100 kPa = 1 bar.

Absolute Pressure = Barometric Pressure + Gauge Pressure.

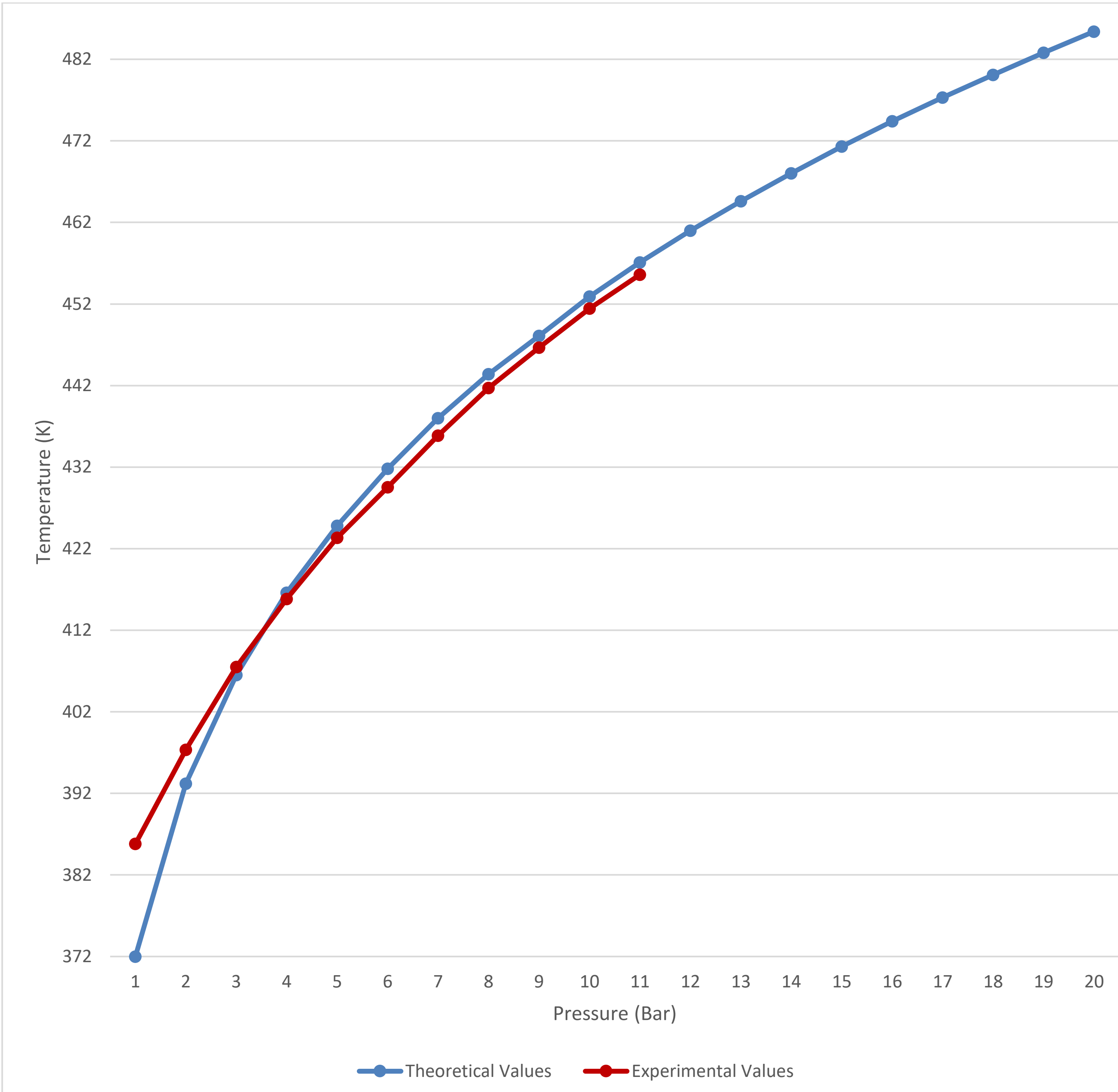
Gauge pressure (Bar)	Absolute Pressure (Bar)	Increasing Temperature (Celsius)	Decreasing Temperature (Celsius)	Mean Temperature (Celsius)
0	0.9	96.8	128.8	112.8
1	1.9	114	134.7	124.35
2	2.9	128.4	140.6	134.5
3	3.9	139.2	146.5	142.85
4	4.9	148.3	152.4	150.35
5	5.9	154.8	158.3	156.55
6	6.9	161.5	164.2	162.85
7	7.9	167.4	170	168.7
8	8.9	172.3	175	173.65
9	9.9	177.1	179.8	178.45
10	10.9	181.1	184.1	182.6

★Results

1) Draw Relation between Temperature and increasing and decreasing pressure.

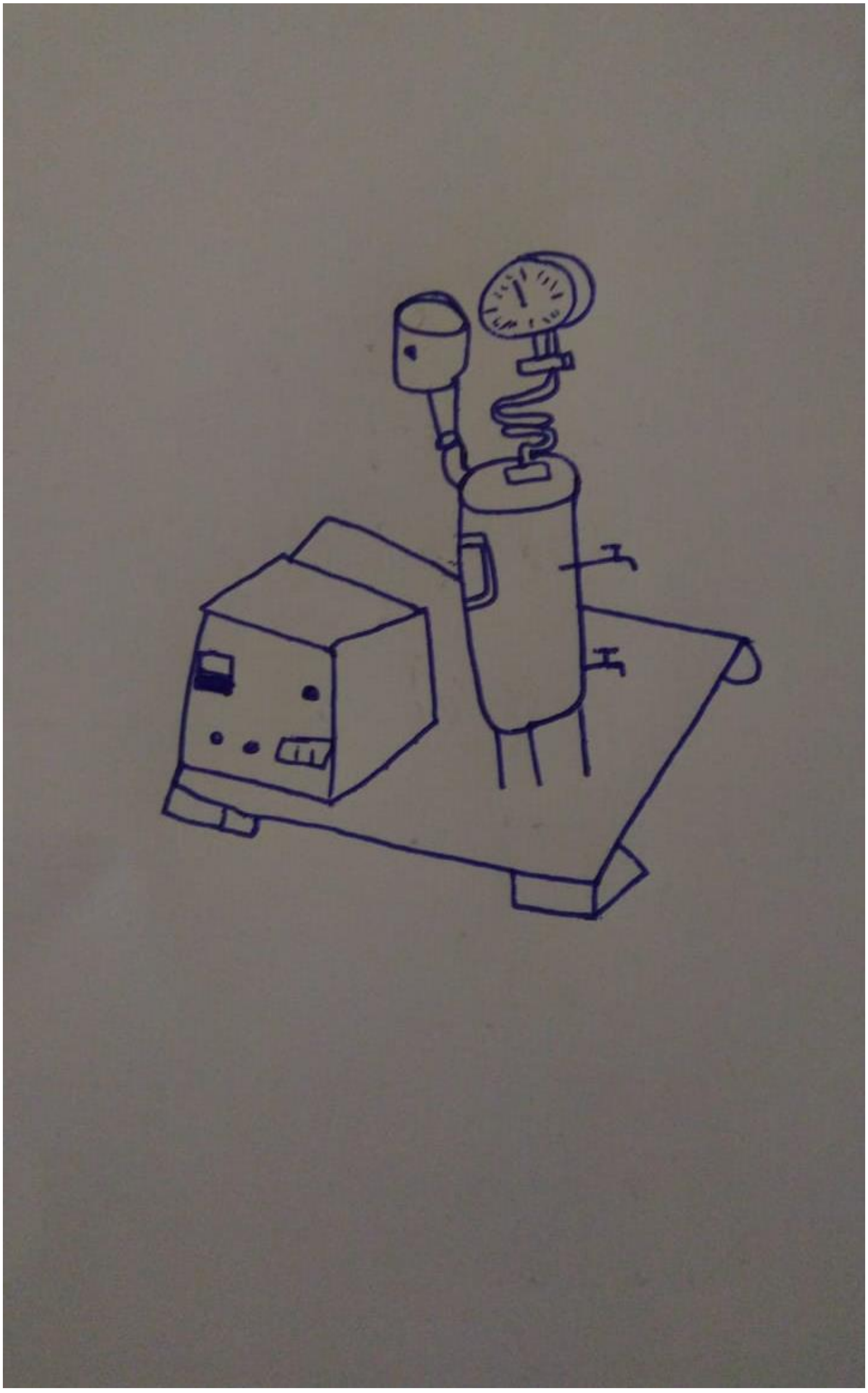


2)



By looking at the two graphs we can see that values are almost identical with small deviation.

3)



- **Sample of calculations**

① For decreasing temperature we need to interpolate

4.9 bar → X

5.9 bar → 158.3°C.

6.9 bar → 164.2°C

$$\frac{158.3 - X}{5.9 - 4.9} = \frac{164.2 - 158.3}{6.9 - 5.9}$$

$158.3 - X = 5.9 \Rightarrow X = 152.4°C$

★ Conclusions

1) a- (90,385.8) || (190,397.35)

$$\frac{dT}{(dP)_{sat}} = \frac{397.35 - 385.8}{100} = 0.1155 \text{ K/kPa}$$

b- (290,407.5) || (490,423.35)

$$\frac{dT}{(dP)_{sat}} = \frac{423.35 - 407.5}{200} = 0.07925 \text{ K/kPa}$$

c- (590,429.55) || (790,441.7)

$$\frac{dT}{(dP)_{sat}} = \frac{429.55 - 441.7}{200} = 0.06075 \text{ K/kPa}$$

Mean slope = (0.06075+0.07925+0.1155)/3 =0.08517 K/kPa.

2)

a- at 385.8 K which equals 112.8 ˚C.

(We need to interpolate to find values of V_{fg} & h_{fg})

99	1.694	2258
112.8	V_{fg}	h_{fg}
120.2	0.8856	2202

V_{fg} = 1.167777 m^3/kg.

h_{fg} = 2221.55 m^3/kg.

$$\frac{dT}{(dP)_{sat}} = \frac{Tv_{fg}}{h_{fg}} = \mathbf{0.202799\ K/kPa}$$

c- at 429.55 K which equals 156.55 ˚C.

(We need to interpolate to find values of V_{fg} & h_{fg})

151.8 0.3748 2109

156.55 V_{fg} h_{fg}

158.8 0.3156 2087

V_{fg} = 0.334629 m^3/kg.

h_{fg} = 2094.07 m^3/kg.

$$\frac{dT}{(dP)_{sat}} = \frac{Tv_{fg}}{h_{fg}} = \mathbf{0.06864\ K/kPa}$$

b- at 407.5 K which equals 134.5 ˚C.

(We need to interpolate to find values of V_{fg} & h_{fg})

133.5   0.6057   2164

134.5 V_{fg} h_{fg}

143.6 0.4623 2134

V_{fg} = 0.5915 m^3/kg.

h_{fg} = 2161.03 m^3/kg.

$$\frac{dT}{(dP)_{sat}} = \frac{Tv_{fg}}{h_{fg}} = 0.03681 \text{ K/kPa}$$

Mean slope = (0.03681+ 0.06864+0.2022799)/3

= 0.1025766 K/kPa.

3) There is a small difference between both mean slopes due to one of these reasons:

a- Personal errors which might happen when we read the scale and don't observe significant figures in our calculations.
b- Random Errors which result from unexpected fluctuations in temperature.
c- Systematic errors like zero pressure gauge.