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Q A1:
Saturation properties of a fluid refer to the thermodynamic properties measured at conditions where the liquid and vapor phases exist together in equilibrium. At this point, the fluid is about to undergo a phase change, such as boiling or condensation. The temperature and pressure at saturation are linked, meaning if one is fixed, the other is automatically determined. These properties help describe how a fluid behaves during phase transitions.

A homogeneous (single-phase) state means the fluid exists completely in one phase, either fully liquid or fully vapor, without any mixture of phases. In this condition, the fluid has uniform properties throughout, and there is no ongoing phase change. Examples include compressed liquid below boiling temperature or superheated vapor above saturation temperature.

Two thermodynamic properties commonly evaluated at saturation are the saturation temperature and saturation pressure. In a homogeneous phase, properties such as density and specific heat capacity are commonly evaluated, because they vary smoothly with temperature and pressure and are useful in analyzing heat transfer and fluid flow.

Q A2:

The general syntax of the `PropsSI` function in CoolProp is:
`PropsSI(Output, Input1, Value1, Input2, Value2, Fluid)`
In this syntax, the user specifies the desired output property (such as density, temperature, or enthalpy), followed by two known input properties and their values, along with the name of the fluid. For example, density can be calculated by giving temperature and pressure as inputs.

The quality parameter `Q` represents the mass fraction of vapor in a two-phase mixture. It is used only under saturation conditions. When `Q = 0`, the fluid is completely in the saturated liquid state, and when `Q = 1`, it is completely in the saturated vapor state. Values between 0 and 1 indicate a mixture of liquid and vapor.

CoolProp uses SI units internally to maintain consistency and accuracy in calculations. Using a single unit system avoids confusion and reduces errors caused by unit conversion.

Q B1:

```
pallavpratibh@pallavs-MacBook-Air code % cd "/Users/pallavpratibh/Desktop/code/z_project"
pallavpratibh@pallavs-MacBook-Air z_project % python -u "/Users/pallavpratibh/Desktop/code/z_project/ass1.py"
Saturation temperature of water at 1 atm = 373.1242958476663 K
```

Q B2:

I am unable to setup gptips2f .

Q B3:

```
[pallavpratibh@pallavs-MacBook-Air ~ % julia
               _
   _       _ _(_)_     |  Documentation: https://docs.julialang.org
  (_)     | (_) (_)    |
   _ _   _| |_  __ _   |  Type "?" for help, "]?" for Pkg help.
  | | | | | | |/ _` |  |
  | | |_| | | | (_| |  |  Version 1.12.4 (2026-01-06)
 _/ |\__'_|_|_|\__'_|  |  Official https://julialang.org release
|__/                   |

julia> using Pkg

julia> Pkg.activate("TiSR_Project")
  Activating project at `~/TiSR_Project`

julia> using CoolProp

julia> T = PropsSI("T", "P", 101325, "Q", 0, "Water")
373.1242958476663

julia> println(T)
373.1242958476663

julia>
```

Q C1:

For Methane, the temperature range was chosen from **150 K to 400 K**, and the pressure range from **1×10^5 Pa to 5×10^6 Pa**. Methane has a critical temperature of about 190.6 K, so temperatures below this allow compressed liquid states at higher pressures, while temperatures above this allow superheated vapor states. This range ensures coverage of both liquid-like and vapor-like behavior.

For R134a, the temperature range was selected from **250 K to 400 K**, and the pressure range from **1×10^5 Pa to 3×10^6 Pa**. Since the critical temperature of R134a is about 374 K, this range includes compressed liquid conditions at lower temperatures and superheated vapor conditions at higher temperatures.

Q D1:

CoolProp is considered a physics-based model because it uses fundamental thermodynamic equations and experimentally validated equations of state to calculate fluid properties. These equations are derived from physical laws such as conservation of energy and thermodynamic equilibrium. Instead of simply fitting data, CoolProp relies on scientifically established relationships between temperature, pressure, and other properties. This makes its predictions reliable even outside the specific data points used during development, as long as they remain within the valid physical range.

A symbolic regression model, on the other hand, learns patterns directly from the dataset without necessarily understanding the underlying physical principles. It tries to find mathematical expressions that fit the data well, but these expressions may not represent the true physics of the system. As a result, when the model is used outside the training range, it may produce unrealistic or incorrect predictions because it has not learned the actual physical behavior, only the observed trends.

Thermodynamic constraints can improve data-driven models by ensuring that the predicted relationships follow physical laws. For example, constraints can prevent negative densities or physically impossible trends.