b) Make a $Z - P$ plot of water using data from the steam tables showing the same information as the $PV$ graph above.

**Problem 2.11:** Determine whether the truncated virial equation is valid for ethane at the following states: a) 10 bar, 25 °C.
b) Saturated vapor at 10 bar. line break
c) 10 bar, −35 °C.
*Additional data:* The boiling point of ethane at 10 bar is −29 °C.

**Problem 2.12:** The R&D division of your company has released the following limited data on proprietary compound X-23:

| $T$ (°C) | $P$ (bar) | $\rho$ (kg/m$^3$) |
|---|---|---|
| 25 | 0.01 | 0.0177 |
| 25 | 20 | 39.8 |
| Saturation pressure at 25 °C: 64.3 bar | | |
| Critical temperature: below 35 °C | | |

Using this incomplete information estimate as best as you can the following:
a) Phase of X-23 at 12 bar, 25 °C.
b) The molar mass of X-23.
c) The second virial coefficient at 25 °C.
d) The required volume of a tank that is needed to store 20 kg of X-23 at 12 bar, 25 C.
e) State clearly and justify as best as you can all your assumptions and the methods you use.

**Problem 2.13:** Methane is stored under pressure in a 1 m$^3$ tank. The pressure in the tank is 20 bar and the temperature is 25 °C.
a) Calculate the compressibility factor of methane in the tank from the virial equation truncated after the second term.
b) What is the amount (moles) of methane in the tank?
c) You want to store twice as much methane in the tank at the same temperature. What will be the pressure in the tank?
d) Is it appropriate to use the virial equation for this problem? Explain.
At 25 °C the second virial coefficient of methane is $-4.22 \times 10^{-5}$ m$^3$/mol.

**Problem 2.14:** Use the truncated virial equation to answer the questions below:
a) A 5 m$^3$ tank contains nitrogen at 110 K, 7 bar. How many kg of nitrogen are in the tank?
b) The tank is cooled until the contents become saturated vapor. What is the pressure and temperature in the tank?