JIF 314 Thermodynamics

Ujian during Kursus intensive
NOV 2008

Instruction: Answer ALL three questions (Jawab semua tiga soalan)

1. Describe the procedure of measuring the ideal gas temperature of the normal boiling point (NBP) of water (the steam point) using constant-volume gas thermometer.

(20 marks)

2. How do you define a state in equilibrium?

(10 marks)

3. Volume expansivity of a hydrostatics system is defined via $\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)$. (*a*) In your opinion, explain why this quantity is almost always a positive number. (*b*) Give an example where the volume expansivity of a hydrostatic system is negative. What is the unit of β?

(5 marks + 5 marks = 10 marks)

4. Question 3.4

   Calculate how much work is done by 1 mole of gas when it expands from a volume of V_0 to $2V$ quasi-statically and isothermally, when the equation of state is $P = \frac{nRT}{V_0}\left(\frac{V}{V_0} - \frac{V_0^2}{V^2}\right)$, where R = 8.31 J/mol·K, n is the amount of gas in mole, T temperature in Kelvin, and V_0 is a constant in unit of m^3. Express your answer in terms of R and T.

(20 marks)

Solution

Q1: 1.10, page 18 – 20 Zemansky. Summerise the essential procedure in brief. Marks are allocated according to (i) General idea (25%) (ii) Description of correct procedure of measurement (25%), (iii) How the conclusion of the numerical value of temperature is finally obtained (25%), (iv) Mathematical formula (25%).

Q2: Page 7, Zemansky, first line in last paragraph: A state of a system in which the thermodynamic coordinates have definitive values that remain constant so long as the external conditions are unchanged is called an equilibrium state.

Q3: Page 34, paragraph following Eq. (2.3).

(*a*) β is almost always a positive number because for most material, they will expand when its temperature rises, i.e.
$\frac{\partial V}{\partial T}$ is positive for these materials. As a consequence the expansivity $\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)$ is positive as well.

(*b*) Water with temperature between 1° - 4° is a good example with negative expansivity.

Q4. Page 47, Problem 2.7, modified, by replacing the original quantities of $K \rightarrow R/V_0$, $T \rightarrow P$, $L_0 \rightarrow V_0$, $L \rightarrow V$:

$P = \frac{RT}{V_0}\left(\frac{V}{V_0} - \frac{V_0^2}{V^2}\right)$. Work done is given by

$$\int_{V_1}^{V_2} PdV = \int_{V_1}^{V_2} \frac{RT}{V_0}\left(\frac{V}{V_0} - \frac{V_0^2}{V^2}\right)dV = \frac{RT}{V_0}\int_{V_1}^{V_2}\left(\frac{V}{V_0} - \frac{V_0^2}{V^2}\right)dV$$

$$= \frac{RT}{V_0}\left[\frac{V^2}{2V_0} + \frac{V_0^2}{V}\right]_{V_1}^{V_2} = \frac{RT}{V_0}\left[\left(\frac{V_2^2}{2V_0} + \frac{V_0^2}{V_2}\right) - \left(\frac{V_1^2}{2V_0} + \frac{V_0^2}{V_1}\right)\right]$$

$$= \frac{RT}{V_0}\left[\left(\frac{(2V_0)^2}{2V_0} + \frac{V_0^2}{(2V_0)}\right) - \left(\frac{(V_0)^2}{2V_0} + \frac{V_0^2}{(V_0)}\right)\right] =$$

$$\frac{RT}{V_0}\left[\left(4 + \frac{1}{2}\right) - \left(\frac{1}{2} + 1\right)\right]V_0 = 3RT$$