4.S: Putting the First Law to Work (Summary)

Learning Objectives

After mastering the material covered in this chapter, one will be able to:

1. Express the total differential of a thermodynamic function in terms of partial differentials involving two independent state variables:

$$dU = \left(\frac{\partial U}{\partial V}\right)_T dV + \left(\frac{\partial U}{\partial T}\right)_V dT \tag{4.S.1}$$

2. Utilize the Euler relation to define an exact differential.
3. Derive and utilize partial differential transformation types I and II:

$$\left(\frac{\partial z}{\partial x}\right)_y = -\left(\frac{\partial z}{\partial y}\right)_x \left(\frac{\partial y}{\partial x}\right)_z$$

and

$$\left(\frac{\partial z}{\partial y}\right)_z = \frac{1}{\left(\frac{\partial y}{\partial z}\right)_x}$$

4. Define and describe the meaning of the **isobaric thermal expansivity** coefficient (α) and the **isothermal compressibility** coefficient (κ_T).
5. Derive expressions for α and κ_T for gases based on an assumed equation of state.
6. Define **internal pressure** and describe the experiment Joule used to attempt to measure it.
7. Calculate a value for the internal pressure based on α and κ_T for a given substance.
8. Derive an expression for the internal pressure of a gas based on an assumed equation of state, given

$$\left(\frac{\partial U}{\partial V}\right)_T = T\frac{\alpha}{\kappa_T} - p$$

9. Demonstrate theat the internal pressure of an ideal gas is zero.
10. Define and describe the physical meaning the Joule-Thomson coefficient.
11. Derive an expression for the Joule-Thomson coefficient in terms of α, C_p, V, and T given

$$\left(\frac{\partial H}{\partial V}\right)_T = \frac{1}{\kappa_T}(T\alpha - 1)$$

12. Demonstrate that the Joule-Thomson coefficient (μ_{JT} for an ideal gas is zero.
13. Derive expressions for the temperature and pressure dependence of enthalpy and internal energy in terms of measurable properties. Use these expressions to calculate changes in enthalpy and internal energy for specific substances based on the values of those measurable properties when the temperature or pressure is changed.

Vocabulary and Concepts

- Euler relation
- exact differential
- internal pressure
- isobaric thermal expansivity
- isothermal compressibility
- Joule-Thomson coefficient
- total differential

References

1. *Encyclopedia Brittannica*. (2016). Retrieved March 15, 2016, from James Prescott Joule: English Physicist: http://www.britannica.com/biography/...Prescott-Joul