CHEM 330 – PHYSICAL CHEMISTRY I – Fall 2026

EXAM 2

Closed book, closed notes
No electronics allowed (discovery of use is an automatic 0)
Calculators may be used (do not use the calculator on your electronic devices)
Write your name clearly in the provided answer book

Time: 1 hour 30 minutes

Problem 1 (20 points)

The equation of state for a Redlich-Kwong gas is the following:

$$P = \frac{RT}{\bar{V} - B} - \frac{A}{T^{1/2}\bar{V}\left(\bar{V} + B\right)}$$

A = 32.2 dm^6•bar•mol^{-2}•K$^{1/2}$ and B = 0.03 dm^3• mol^{-1} are constants, and the other symbols have their usual meanings.

(a) Derive an expression for the work done in a reversible isothermal expansion of a Redlich-Kwong gas from an initial molar volume $\bar{V}_1$ to a final molar volume $\bar{V}_2$. (6 points)

(b) Calculate the numerical value of the work (in kJ/mol) when $\bar{V}_1$ = 1.0 dm^3•mol^{-1} and $\bar{V}_2$ = 5.0 dm^3•mol^{-1} at a temperature T = 300 K. (4 points)

(c) What is the numerical value of work done (in kJ/mol) for an ideal gas under the same conditions? (10 points)

Problem 2 (15 points)

(a) Given that H = U + PV, what is the value of $\left(\frac{\partial H}{\partial V}\right)_T$ for an ideal gas? The internal energy of an ideal gas only depends on temperature. (7 points)

(b) When an ideal gas is compressed adiabatically and reversibly to half its original volume, the temperature increases from 273 K to 433 K. Assuming that C_V is independent of temperature, calculate the value of $C_V / \left(nR\right)$. (8 points)

Problem 3 (15 points)

Obtain an expression for the entropy change (ΔS) in taking an ideal gas from a state with temperature T_1 and pressure P_1 to a state with temperature T_2 and pressure P_2. Assume that C_P is independent of temperature and the enthalpy change is given by dH = TdS + VdP.

Useful Information:

R = 0.083 dm^3•bar•mol^{-1}•K^{-1}

1 bar = 10^5 N•m^{-2}

1 J = 1 N•m

$$\int \frac{dx}{x\left(ax + b\right)} = -\frac{1}{b}\ln\left(\frac{ax + b}{x}\right)$$

EXAM 2 – SOLUTIONS

Problem 1

(a) Equation of state for a Redlich-Kwong gas

$$P = \frac{RT}{\bar{V} - B} - \frac{A}{T^{1/2}\,\bar{V}(\bar{V}+B)}$$

For a reversible isothermal expansion from $\bar{V}_1$ to $\bar{V}_2$

$$W_{rev} = -\int_{\bar{V}_1}^{\bar{V}_2} P \cdot d\bar{V}$$

$$= -RT \int_{\bar{V}_1}^{\bar{V}_2} \frac{d\bar{V}}{\bar{V}-B} + \frac{A}{T^{1/2}} \int \frac{d\bar{V}}{\bar{V}(\bar{V}+B)}$$

$$= RT \ln\left[\frac{\bar{V}_1 - B}{\bar{V}_2 - B}\right] + \frac{A}{BT^{1/2}} \ln\left[\frac{\bar{V}_2(\bar{V}_1+B)}{\bar{V}_1(\bar{V}_2+B)}\right]$$

(b) $RT = (0.083\ dm^3 \cdot bar \cdot mol^{-1} \cdot K^{-1}) \times 300\ K$

$= 24.9\ dm^3 \cdot bar \cdot mol^{-1}$

$$RT \ln\left[\frac{\bar{V}_1 - B}{\bar{V}_2 - B}\right] = 24.9 \ln\left[\frac{1 - 0.03}{5 - 0.03}\right]$$

$$= -40.68 \ dm^3.bar.mol^{-1}$$

$$\frac{A}{BT^{1/2}} \cdot \ln\left[\frac{\bar{V}_2(\bar{V}_1 + B)}{\bar{V}_1(\bar{V}_2 + B)}\right] = \frac{32.2}{0.03 \times \sqrt{300}} \times \ln\left[\frac{5 \times 1.03}{1 \times 5.03}\right]$$

$$= \frac{32.2}{0.03 \times 17.32} \times \ln\left[\frac{5.15}{5.03}\right]$$

$$= 61.97 \times 0.02$$

$$= 1.24 \ dm^3.bar.mol^{-1}$$

$$W_{rev} = (-40.68 + 1.24)$$

$$= -39.44 \ dm^3.bar.mol^{-1}$$

$$= -39.44 \times 10^{-3} \ m^3 \times 10^5 \ Nm^{-2} \ mol^{-1}$$

$$= -39.44 \times 10^2 \ Nm \ mol^{-1}$$

$$= -3944 \ J/mol$$

(c) For an ideal gas

$$w_{rev} = -RT \ln \frac{\bar{V}_2}{\bar{V}_1}$$

$$= -0.083 \times 300 \ln 5$$

$$= -24.9 \ln(5)$$

$$= -40.08 \text{ dm}^3 \text{ bar mol}^{-1}$$

$$= -40.08 \times 10^{-3} \text{ m}^3 \times 10^5 \text{ Nm}^{-2} \text{ mol}^{-1}$$

$$= -4008 \text{ J/mol}$$

Problem 2

(a) $H = U + PV$

$$\left(\frac{\partial H}{\partial V}\right)_T = \left(\frac{\partial V}{\partial V}\right)_T + \left(\frac{\partial P}{\partial V}\right)_T^V + P$$

For an ideal gas

$$P = \frac{nRT}{V}$$

$$\left(\frac{\partial P}{\partial V}\right)_T = -\frac{nRT}{V^2}$$

$$\left(\frac{\partial U}{\partial V}\right)_T = 0 \quad \text{for an ideal gas}$$

$$V\left(\frac{\partial P}{\partial V}\right)_T = -\frac{nRT \cdot V}{V^2} = -\frac{nRT}{V}$$

$$= -P$$

Thus, $\left(\frac{\partial H}{\partial V}\right)_T = 0$ for an ideal gas.

(b) Adiabatic and reversible compression of an ideal gas

$$q_{rev} = 0$$

$$\delta w_{rev} = -P dV$$

$$\Delta U = C_V dT$$

Thus,

$$C_V dT = -P dV$$

$$C_V dT = -\frac{nRT\, dV}{V}$$

Thus, integrating both sides

$$\int_{T_1}^{T_2} \frac{C_V \, dT}{T} = -nR \int_{V_1}^{V_2} \frac{dV}{V}$$

$C_V \longrightarrow$ independent of T

$$C_V \ln\left(\frac{T_2}{T_1}\right) = nR \ln\left(\frac{V_1}{V_2}\right)$$

$$C_V \ln\left(\frac{433}{273}\right) = nR \ln(2)$$

$$0.46\, C_V = 0.69\, nR$$

$$\frac{C_V}{nR} = 1.5$$

Problem 3

Initial state : T_1, P_1

Final state : T_2, P_2

$$dH = TdS + VdP$$

$$dS = \frac{dH}{T} - \frac{VdP}{T}$$

For an ideal gas,

$$PV = nRT$$

$$\frac{V}{T} = \frac{nR}{P}$$

$$dS = C_p \cdot \frac{dT}{T} - \frac{nR\,dP}{P}$$

Integrating, since $C_p \neq f(T)$

$$\Delta S = C_p \ln\left(\frac{T_2}{T_1}\right) - nR \ln\left(\frac{P_2}{P_1}\right)$$