



Indian Institute of Science Education and Research Kolkata
Endsem (Spring Semester)

Subject: Elements of Chemistry-II

Subject Code: CH1201

Full Marks: 35

Time Allotted: 2 hours

Q1. Tick (✓) the right answer to the following questions:

(i) Which of the following quantities is a state function? (1)

- A) Work (w) B) Heat (q) ☒ C) Internal Energy (U) D) Path length (l)

(ii) The Joule's coefficient (μ_J) is defined as: (1)

- A) $\left(\frac{\partial T}{\partial V}\right)_P$ B) $\left(\frac{\partial U}{\partial V}\right)_T$ ☒ C) $\left(\frac{\partial T}{\partial V}\right)_U$ D) $\left(\frac{\partial T}{\partial P}\right)_H$

(iii) Which of the following thermodynamic potentials ensures that a process is spontaneous at constant temperature and volume? (G=Gibbs; A=Helmholtz, H=Enthalpy). (1)

- A) $\Delta G < 0$ B) $\Delta S = 0$ ☒ C) $\Delta A < 0$ D) $\Delta H < 0$

(iv) Which of the following thermodynamic potentials describe that a process is spontaneous for isolated system? (1)

- ☒ A) ΔS B) ΔG C) ΔA D) ΔH

(v) Which of the following processes has $\Delta S = 0$? (1)

- ☒ A) Reversible adiabatic expansion B) Irreversible isothermal expansion
C) Free expansion D) Mixing of gases

(vi) The efficiency of a Carnot engine operating between 400 K and 300 K is: (1)

- ☒ A) 25% B) 33% C) 75% D) 50%

(vii) The entropy change in surrounding for a process at 300 K in which 10 kJ of heat is released by the system is: (1)

- ☒ A) -33.3 JK^{-1} B) $+33.3 \text{ JK}^{-1}$ C) $+0.0333 \text{ JK}^{-1}$ D) -0.0333 JK^{-1}

(viii) A gas undergoes a Joule–Thomson expansion from 100 bar to 40 bar. The Joule–Thomson coefficient for the gas is $\mu_{JT}=0.25 \text{ K/bar}$, and the initial temperature of the gas is 300 K. Assume the Joule–Thomson coefficient remains constant over the entire pressure range. What is the final temperature of the gas after the expansion? (1)

- ☒ A) 280 K B) 285 K C) 290 K D) 295 K

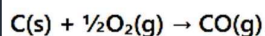


Q2. (i) State Hess's law.

(ii) Using Hess's law and the following thermochemical equations calculate the standard enthalpy change (ΔH°) for the combustion of *carbon to form carbon monoxide*:



Determine the standard enthalpy change for the following reaction:



(You may also use Law of Lavoisier and Laplace, but then state the law and you must mention where you applied.)

(iii) Calculate the standard Gibbs free energy change (ΔG°) for the same combustion reaction of *carbon to form carbon monoxide* reaction at 298 K. (Given, the standard entropy change, ΔS° is +89.5 J/mol·K). (put correct input values; while you may skip final calculations which requires calculator).

(iv) Comment on the spontaneity of the reaction at 298 K.

(v) Predict how the spontaneity of the above reaction would change at lower temperature. Justify your answer using the Gibbs equation ($\Delta G = \Delta H - T\Delta S$). (1+3+2+1+2)

Q3. (i) A sample of one mole argon gas undergoes a reversible process where both Temperature (T) and Volume (V) simultaneously change. Combining First and Second Law of Thermodynamics derive the following expression of entropy change:

$$\Delta S = C_V \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{V_2}{V_1}\right)$$

(ii) Calculate the entropy change when this 1 mole of argon gas at 25°C and 1.00 bar in a container of volume 0.8 dm³ is allowed to expand to 1.2 dm³ and is simultaneously heated to 75°C. ($C_V = 3/2 R$; where, $R = 8.314 \text{ J/mol.K}$).

(iii) Now suppose the same sample of argon gas undergoes a reversible adiabatic expansion. Using the general mathematical form of the First Law of Thermodynamics, derive an expression to determine the final temperature of the gas in terms of its initial and final volumes.

(iv) Determine whether the above adiabatic expansion process results in cooling or heating of the gas. Justify the temperature change during the above reversible adiabatic expansion, even though no heat is exchanged with the surroundings. (3+1.5+3+1.5)

Q4. The change in Helmholtz Free Energy is expressed as $dA = -SdT - PdV$. Using this relation answer the following:

(i) Identify X and Y in the following Maxwell relation: $\left(\frac{\partial P}{\partial T}\right)_V = \left(\frac{\partial S}{\partial X}\right)_Y$

(ii) Using the above Maxwell's relation, show that: $\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$

(iii) Using the above Thermodynamic Equation of State and Maxwell relation, prove:

$$\bar{C}_P - \bar{C}_V = T \left(\frac{\partial P}{\partial T}\right)_V \left(\frac{\partial V}{\partial T}\right)_P$$

(iv) Using the above expression, for one mole ideal gas, derive, $\bar{C}_P - \bar{C}_V = R$ (1+2+4+2)