

BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND AENGINEERING

CHEMISTRY DEPARTMENT

HBSch ChT and HBSchEdCh

AUG 2024

COURSE: CH101 / PHYSICAL CHEMISTRY I

2 HOURS

Answer Question One (1), two (2) questions from section A, and any two (2) questions from section B.

1. Consider a 20 L sample of moist air at 60 °C and 1 atm in which the partial pressure of water vapor is 0.120 atm. Assume that dry air has the composition: 78.0 mole percent N₂, 21.0 mole percent O₂, and 1.00 mole percent Ar.

- a) What are the mole percentages of each of the gases in the moist air sample?

[8 marks]

- b) The percent relative humidity is defined as $\% RH = \frac{P_{H_2O}}{P^*_{H_2O}}$ where P_{H_2O} is the partial pressure of water in the sample and $P^*_{H_2O} = 0.197 \text{ atm}$ is the equilibrium vapor pressure of water at 60°C. The gas is compressed at 60 °C until the relative humidity is 100 %. What volume does the mixture now occupy?

[6 marks]

- c) What fraction of the water will be condensed if the total pressure of the mixture is isothermally increased to 200 atm?

[6 marks]

SECTION A: Answer TWO questions from this section

2. Consider the equilibrium $\text{CO}_{(g)} + \text{H}_2\text{O}_{(g)} \leftrightarrow \text{CO}_{2(g)} + \text{H}_{2(g)}$. At 1000 K, the composition of the reaction mixture is

Substance	$\text{CO}_{2(g)}$	$\text{H}_{2(g)}$	$\text{CO}_{(g)}$	$\text{H}_2\text{O}_{(g)}$
Mole %	27.1	27.1	22.9	22.9

- a) Calculate K_P and $\Delta G_{\text{reaction}}$ at 1000 K. [8 marks]

- b) Given the answer to part (a), use the provided ΔH_f values to calculate $\Delta G_{\text{reaction}}$ at 298.15 K. Assume that $\Delta H_{\text{reaction}}$ is independent of temperature. [12 marks]

substances	$\Delta H_f / \text{KJmol}^{-1}$
CO_2	-393.5
CO	-110.5
H_2O	-241.8

3. a) Why is $\Delta H_{\text{sublimation}} = \Delta H_{\text{fusion}} + \Delta H_{\text{vaporization}}$? [2 marks]

- b) The phase diagram of NH_3 can be characterized by the following information. The normal melting and boiling temperatures are 195.2 and 239.82 K, respectively, while the triple point pressure and temperature are 6077 Pa and 195.41 K, respectively. The critical point parameters are 112.8×10^5 Pa and 405.5 K. Make a sketch of the P-T phase diagram (*not necessarily to scale*) for NH_3 . State which and how many phases are present. [10 marks]

- c) For water, $\Delta H_{\text{vaporization}}$ is $40.65 \text{ kJ mol}^{-1}$, and the normal boiling point is 373.15 K. Calculate the boiling point for water on the top of a mountain of height 5500 m, where the normal barometric pressure is 380 Torr. [8 marks]

4. a) Define the following terms:

- i) Adiabatic process
- ii) Diathermic wall
- iii) State function
- iv) Eutectic mixture
- v) Super critical fluid

[5 marks]

b) A pellet of Zn of mass 10.0 g is dropped into a flask containing dilute H_2SO_4 at a pressure $P = 1.00$ bar and temperature $T = 298$ K. What is the reaction that occurs? Calculate w for the process.

[7 marks]

c) 3.00 moles of an ideal gas at 27.0°C expands isothermally from an initial volume of 20.0 dm^3 to a final volume of 60.0 dm^3 . Calculate w for this process:

- (i) for expansion against a constant external pressure of 1.00×10^5 Pa, and
- (ii) for a reversible expansion.

[8 marks]

SECTION B: Answer TWO questions from this section

5. a) State the First law of thermodynamics.

[2 marks]

b) A sealed flask with a capacity of 1.00 dm^3 contains 5.00 g of ethane. The flask is so weak that it will burst if the pressure exceeds 1.00×10^6 Pa. At what temperature will the pressure of the gas exceed the bursting temperature?

[6 marks]

c) A cup of water at 278 K (the system) is placed in a microwave oven and the oven is turned on for one minute, during which it begins to boil. Which of q , w , and ΔU are positive, negative or zero?

[6 marks]

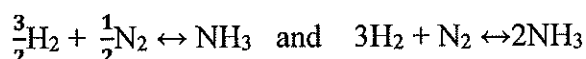
d) What is wrong with the following statement?: *Burns caused by steam at 100°C can be more severe than those caused by water at 100°C because steam contains more heat than water.* Rewrite the sentence to convey the same information in a correct way.

[6 marks]

6 a) 3.00 moles of a gas are compressed isothermally from 60.0 L to 20.0 L using a constant external pressure of 5.00 atm. Calculate q , w , ΔU , and ΔH . [8 marks]

b) One mole of an ideal gas for which $C_{V,m} = 20.8 \text{ J K}^{-1} \text{ mol}^{-1}$ is heated from an initial temperature of 0°C to a final temperature of 275°C at constant volume. Calculate q , w , ΔU and ΔH for this process. [8 marks]

c) What is the relationship between the K_P for the two reactions? [4 marks]



7. a) Classify the following processes as spontaneous or not spontaneous and explain your answer.

- i) The reversible isothermal expansion of an ideal gas.
- ii) The vaporization of superheated water at 102°C and 1 bar.
- iii) The constant pressure melting of ice at its normal freezing point by the addition of an infinitesimal quantity of heat.
- iv) The adiabatic expansion of a gas into a vacuum.

[8 marks]

b) The heat capacity of solid lead oxide is given by

$$C_{P,m} = 44.35 + 1.47 \times 10^{-3} \frac{T}{K} \text{ in units of } \text{J K}^{-1} \text{ mol}^{-1}.$$

Calculate the change in enthalpy of 1 mol of $\text{PbO}_{(s)}$ if it is cooled from 500 K to 300 K at constant pressure.

[8 marks]

c) A process involving an ideal gas is carried out in which the temperature changes at constant volume. For a fixed value ΔT , the mass of the gas is doubled. The process is repeated with the same initial mass and ΔT is doubled. For which of these processes is ΔS greater, and why?

[4 marks]

END OF QUESTION PAPER