

BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE

CHEMISTRY DEPARTMENT

HBSced CHEMISTRY and HBSc CHEMICAL TECHNOLOGY

COURSE: CH 101: PHYSICAL CHEMISTRY I

AUG 2023

2 HOURS

ANSWER QUESTION ONE (1) and FOUR (4) OTHERS. Each question carries 20 marks.

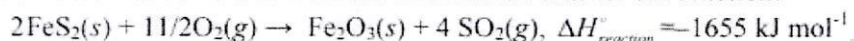
1. (a) Consider the equilibrium $\text{C}_2\text{H}_{6(g)} \leftrightarrow \text{C}_2\text{H}_{4(g)} + \text{H}_{2(g)}$. At 1000 K and a constant total pressure of 1 bar, $\text{C}_2\text{H}_{6(g)}$ is introduced into a reaction vessel. At equilibrium, the composition of the mixture in mole percent is $\text{H}_{2(g)}$: 26%, $\text{C}_2\text{H}_{4(g)}$: 26%, and $\text{C}_2\text{H}_{6(g)}$: 48%.

(i) Calculate K_P at 1000 K. [4 marks]

(ii) If $\Delta H_{\text{reaction}}^\circ = 137.0 \text{ kJ mol}^{-1}$, calculate the value of K_P at 298.15 K. [3 marks]

(iii) Calculate $\Delta G_{\text{reaction}}^\circ$ for this reaction at 298.15 K. [2 marks]

- (b) Calculate the standard enthalpy of formation of $\text{FeS}_{2(s)}$ at 300 °C from the data below at 25 °C and from the information that for the reaction:



Assume that the heat capacities are independent of temperature.

Substance	Fe(s)	FeS ₂ (s)	Fe ₂ O ₃ (s)	S(rhombic)	SO ₂ (g)
ΔH_f° (kJ mol ⁻¹)			-824.2		-296.81
$C_{P,m}/R$	3.02	7.48		2.72	

[6 marks]

- (c) One mole of an ideal gas, for which $C_{V,m} = 3/2 R$, initially at 20.0 °C and $1.00 \times 10^6 \text{ Pa}$ undergoes a two stage transformation. For the stage described below, calculate the final pressure, as well as q , w , ΔU and ΔH .

(i) The gas is expanded isothermally and reversibly until the volume doubles. [5 marks]

SECTION A: Answer TWO questions from this section

2. (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 Cu 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]**
3. (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]**
4. (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 . **[6 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. **[10 marks]**
- (c) What is the relationship between the K_p for the two reactions
 $3/2\text{H}_2 + 1/2\text{N}_2 \rightarrow \text{NH}_3$ and $3\text{H}_2 + \text{N}_2 \rightarrow 2\text{NH}_3$? **[4 marks]**

SECTION B: Answer **TWO** questions from this section

5. (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? Why? **[4 marks]**
6. (a) Why is $\Delta H_{\text{sublimation}} = \Delta H_{\text{fusion}} + \Delta H_{\text{vaporization}}$? **[3 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, 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. **[12 marks]**
- (d) For water, $\Delta H_{\text{vaporization}}$ is 40.65 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. **[5 marks]**
7. (a) One mole of N_2 at 20.5°C and 6.00 bar undergoes a transformation to the state described by 145°C and 2.75 bar. Calculate ΔS if
- $$\frac{C_{P,m}}{\text{J mol}^{-1} \text{K}^{-1}} = 30.81 - 11.87 \times 10^{-3} \frac{T}{\text{K}} + 2.3968 \times 10^{-5} \frac{T^2}{\text{K}^2} - 1.0176 \times 10^{-8} \frac{T^3}{\text{K}^3}$$
- [10 marks]**

- (b) Draw the phase diagrams of water and carbon dioxide. What are the main differences between these two diagrams; explain why these differences exist. **[10 marks]**

END OF QUESTION PAPER