

BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE

CHEMISTRY DEPARTMENT

BScED and CHEMICAL TECHNOLOGY

COURSE: CH101:

PHYSICAL CHEMISTRY I

TIME:

2 HOURS

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

1. (a) State the first law of thermodynamics. [2 marks]

- (b) For silver, $C_p = 23.43 + 0.00628T (J / Kmol)$. Calculate ΔH if 3 moles of silver are raised from 25 °C to the melting point, 961 °C, under 1 atm pressure. [5 marks]

- (c) State the phase rule, and define all terms in this rule. [4 marks]

- (d) Consider the equilibrium $NO_2(g) \leftrightarrow NO(g) + 1/2O_2(g)$. One mole of $NO_2(g)$ is placed in a vessel and allowed to come to equilibrium at a total pressure of 1 bar. An analysis of the contents of the vessel gives the following results:

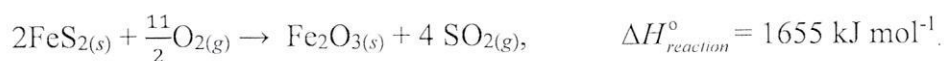
T	700 K	800 K
$\frac{P_{NO}}{P_{NO_2}}$	0.872	2.50

- i. Calculate K_p at 700 and 800 K. [4 marks]
- ii. Calculate $\Delta G_{reaction}^{\circ}$ and $\Delta H_{reaction}^{\circ}$ for this reaction at 298.15 K. Assume that $\Delta H_{reaction}^{\circ}$ is independent of temperature. [5 marks]

SECTION A: Answer TWO (2) questions from this section.

2. (a) A chemical reaction occurs under isochoric conditions, in a container with diathermic walls. Will the temperature of the surroundings increase, decrease, or remain same in this process? Explain. [4 marks]
- (b) 3.00 moles of an ideal gas at 27.0°C expands isothermally from an initial volume of 20.0 dm³ to a final volume of 60.0 dm³. 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]

- (c) 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.

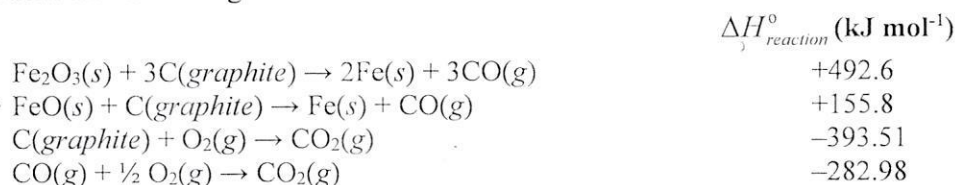
Substance	$\text{Fe}(s)$	$\text{FeS}_2(s)$	$\text{Fe}_2\text{O}_3(s)$	$\text{S}(\text{rhombic})$	$\text{SO}_2(g)$
ΔH_f° (kJ mol ⁻¹)			-824.2		-296.81
$C_{P,m}/R$	3.02	7.48		2.72	

[6 marks]

- (e) Under what conditions are ΔH and ΔU for a reaction involving gases and/or liquids or solids identical?

[2 marks]

3. (a) From the following data at 25°C



Calculate the standard enthalpy of formation of $\text{FeO}(s)$ and of $\text{Fe}_2\text{O}_3(s)$.

[6 marks]

- (b) 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 each of the stages described below, calculate the final pressure, as well as q , w , ΔU and ΔH .

- The gas is expanded isothermally and reversibly until the volume doubles. [4 marks]
- Beginning at the end of the first stage, the temperature is raised to 80.0°C at constant volume. [6 marks]
- Also calculate q , w , ΔU and ΔH for the complete process. [4 marks]

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

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

[8 marks]

- (b) (i) Under what conditions is $dA \leq 0$ a condition that defines the spontaneity of a process? [2 marks]
- (ii) Under what conditions is $dG \leq 0$ a condition that defines the spontaneity of a process? [2 marks]
- (c) Consider the equilibrium $\text{C}_2\text{H}_6(\text{g}) \leftrightarrow \text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g})$. At 1000 K and a constant total pressure of 1 bar, $\text{C}_2\text{H}_6(\text{g})$ is introduced into a reaction vessel. At equilibrium, the composition of the mixture in mole percent is $\text{H}_2(\text{g})$: 26%, $\text{C}_2\text{H}_4(\text{g})$: 26%, and $\text{C}_2\text{H}_6(\text{g})$: 48%.
- (i) Calculate K_P at 1000 K. [3 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]
- a) $\text{C}_2\text{H}_6(\text{g}) \rightarrow \text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g})$

SECTION B: Answer **TWO (2)** questions from this section.

5. (a) State the third 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 $1.00 \times 10^6 \text{ Pa}$. 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 . [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]
7. (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] (a) An electric motor produces 56 kJ of energy each second as mechanical work and

loses 2 kJ as heat to the surroundings, What is the change in the internal energy of the motor each second?

[4 marks]

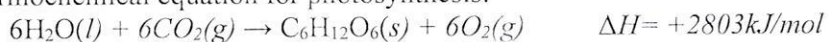
- (b) Calculate the work done when 50 g of iron reacts with hydrochloric acid to produce $\text{FeCl}_2(\text{aq})$ and hydrogen in:

(a) a closed vessel of fixed volume,

(b) an open beaker at 25°C .

[6 marks]

- (c) Calculate the solar energy required to produce 5255 g of $\text{C}_6\text{H}_{12}\text{O}_6$ given the thermochemical equation for photosynthesis:



[5 marks]

- (d) What mass of iron must be in a hot pack to provide 335 kJ of heat when the iron reacts with oxygen and is converted to iron (III) oxide according to the following thermochemical equation?



[5 marks]

END OF QUESTION PAPER