Exam-A

BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE

CHEMISTRY DEPARTMENT

MAR 2023

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**.

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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 pint, 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 $\Delta G^\circ_{reaction}$ and $\Delta H^\circ_{reaction}$ for this reaction at 298.15 K. Assume that $\Delta H^\circ_{reaction}$ 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 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 x 10^5 Pa, and (ii) for a reversible expansion. **[8 marks]**

(c) Calculate the standard enthalpy of formation of $FeS_2(s)$ at 300°C from the data below at 25°C and from the information that for the reaction

$$2FeS_{2(s)} + \frac{11}{2}O_{2(g)} \rightarrow Fe_2O_{3(s)} + 4\ SO_{2(g)}, \qquad \Delta H^\circ_{reaction} = 1655\ \text{kJ mol}^{-1}.$$

Assume that the heat capacities are independent of temperature.

Substance	$Fe(s)$	$FeS_2(s)$	$Fe_2O_3(s)$	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]

(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

	$\Delta H^\circ_{reaction}$ (kJ mol^{-1})
$Fe_2O_3(s) + 3C(graphite) \rightarrow 2Fe(s) + 3CO(g)$	+492.6
$FeO(s) + C(graphite) \rightarrow Fe(s) + CO(g)$	+155.8
$C(graphite) + O_2(g) \rightarrow CO_2(g)$	–393.51
$CO(g) + ½\ O_2(g) \rightarrow CO_2(g)$	–282.98

Calculate the standard enthalpy of formation of $FeO(s)$ and of $Fe_2O_3(s)$.

[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 x 10^6 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.

(i) The gas is expanded isothermally and reversibly until the volume doubles. **[4 marks]**

(ii) Beginning at the end of the first stage, the temperature is raised to 80.0°C at constant volume. **[6 marks]**

(iii) 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.

(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) (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 $C_2H_6(g) \leftrightarrow C_2H_4(g) + H_2(g)$. At 1000 K and a constant total pressure of 1 bar, $C_2H_6(g)$ is introduced into a reaction vessel. At equilibrium, the composition of the mixture in mole percent is $H_2(g)$: 26%, $C_2H_4(g)$: 26%, and $C_2H_6(g)$: 48%.

(i) Calculate K_P at 1000 K. **[3 marks]**

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

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

a) $C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g)$

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 1.00×10^6 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. **[6 marks]**

(b) One mole of an ideal gas for which $C_{V,m} = 20.8$ J K^{-1} 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

$3/2H_2 + 1/2N_2 \rightarrow NH_3$ and $3H_2 + N_2 \rightarrow 2NH_3$?[4 marks] (a) An electric motor produces56 kJ of energy each second as mechanical work and

looses 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 $FeCl_2(aq)$ 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 $C_6H_{12}O_6$ given the thermochemical equation for photosynthesis:

$6H_2O(l) + 6CO_2(g) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$ $\quad \Delta H = +2803 kJ/mol$

[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?

$2\ Fe(s) + 1.5\ O_2(g) \rightarrow Fe_2O_3(s);$ $\quad \Delta H^{\circ} = -824.2\ kJ/mol$

[5 marks]

END OF QUESTION PAPER