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University Examinations 2023/2024

SECOND YEAR, FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE CHEMISTRY, BACHELOR OF SCIENCE IN EDUCATION SCIENCE

SCH 3201: PHYSICAL CHEMISTRY II

DATE: DECEMBER 2023 **TIME:2 HOURS**

INSTRUCTIONS: *answer question one and any other two questions*

QUESTION ONE (30 MARKS)

(a) Define the joule in terms of SI base units. (2 marks)

(b) Describe a simple bomb calorimeter. What measurements are needed to determine the heat of reaction? (3 marks)

(c) State the first Law of thermodynamics according to:

i. Energy and its conservation (3 marks)

ii. Internal energy of a system (3 marks)

(d) Write the formulas for the following basic concepts as used in thermodynamics

i. Expansion against constant pressure (3 marks)

ii. Isothermal reversible expansion (3 marks)

(e) Write the van der Waals equation and explain the terms in it (6 marks)

(f) Using the following definition of reduced variables, explain the principle of corresponding states. (4 marks)

$$V_r = \frac{V_m}{V_c} \qquad p_r = \frac{p}{p_c} \qquad T_r = \frac{T}{T_c}$$

(g) The standard reaction enthalpy for the hydrogenation of propene

$CH_2{=}CHCH_3(g) + H_2(g) \rightarrow CH_3CH_2CH_3(g)$

is -124 kJ mol^{-1}. The standard reaction enthalpy for the combustion of propane

$CH_3CH_2CH_3(g) + 5\,O_2(g) \rightarrow 3\,CO_2(g) + 4\,H_2O(l)$

is -2220 kJ mol^{-1}. Calculate the standard enthalpy of combustion of propene.

(3 marks)

QUESTION TWO

(a) Define/explain the following terms

i. Heat capacity (C) (4 marks)

ii. Standard heat of formation (3 marks)

(b) The change in molar internal energy when $CaCO_3(s)$ as calcite converts to another form, aragonite, is +0.21 kJ mol^{-1}. Calculate the difference between the molar enthalpy and internal energy changes when the pressure is 1.0 x 10^5 Pa given that the densities of the calcite and aragonite are 2.71 g cm^{-3} and 2.93 g cm^{-3}, respectively. (5 marks)

(c) Calculate the work in kilojoules done during a reaction in which the volume expands from 12.0 L to 14.5 L against an external pressure of 5.0 atm. (4 marks)

(d) Which of the following reactions are spontaneous under standard conditions at 25 °C, and which are nonspontaneous? Explain (4 marks)

i. AgNO3(aq) + NaCl(aq) → AgCl(s) + NaNO3(aq) $\Delta G° = -55.7$ kJ

ii. 2 C(s) + 2 H_2(g) → C_2H_4(g) $\Delta G° = 68.1$ kJ

QUESTION THREE (20 MARKS)

(a) Predict (and explain) whether $\Delta S°$ is likely to be positive or negative for each of the following reactions: (6 marks)

$$H_2C{=}CH_2(g) + Br_2(g) \longrightarrow BrCH_2CH_2Br(l)$$

$$2\,C_2H_6(g) + 7\,O_2(g) \longrightarrow 4\,CO_2(g) + 6\,H_2O(g)$$

(b) A chemical reaction takes place in a container of cross-sectional area 50.0 cm^2. As a result of the reaction, a piston is pushed out through 15 cm against an external pressure of 121000 Pa. Calculate the work done by the system. (6 marks)

(c) Aqueous silver ion reacts with aqueous chloride ion to yield a white precipitate of solid silver chloride Ag+ (aq) + Cl- (aq) → AgCl (s). When 10.0 mL of 1.00 M $AgNO_3$ solution is added to 10.0 mL of 1.00 M NaCl solution at 25 °C in a calorimeter, a white precipitate of AgCl forms and the temperature of the aqueous mixture increases to 32.6 °C. Assuming that the specific heat of the aqueous mixture is 4.18 J/(g.°C), that the density of the mixture is 1.00 g/mL, calculate ΔH in kJ for the reaction. [8 marks]

QUESTION FOUR

(a) State Hess's law of heat summation (3 marks)

(b) We can show that by definition, enthalpy is defined as H = U + pV and implies that the change in enthalpy is equal to the energy supplied as heat (q) at constant pressure (provided the system does no additional work): thus dH = dq (heat transferred at constant pressure). Show the justification proof. (11 marks)

(c) Define the following terms

i. Compression factor (2 marks)

ii. Virial coefficients (2 marks)

iii. Condensation (2 marks)