# MACHAKOS UNIVERSITY

**University Examinations 2020/2021 Academic Year**

**SCHOOL OF PURE AND APPLIED SCIENCES**

**DEPARTMENT OF PHYSICAL SCIENCES**

**SECOND YEAR FIRST SEMESTER EXAMINATION FOR**

**BACHELOR OF EDUCATION (SPECIAL NEEDS)**

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**SCH 201: CHEMICAL THERMODYNAMICS**

**DATE: 19/8/2021** **TIME: 11.00-1.00 PM**

**INSTRUCTIONS:**

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

**Useful constants**

R=8.314J/mol k or R=0.08206L.atm/mol k

$C_p=\frac{5}{2}R$ $C_v=\frac{3}{2}R$(monoatomic ideal gases)

$C_p=\frac{7}{2}R$ $C_v=\frac{5}{2}R$(Diatomic ideal gases)

STP (T=273 K, 1atm=101325$Nm^{-2}$, V=22.415$dm^3$)

$\Delta U=nC_vdT$

$\Delta H=nC_PdT$

**QUESTION ONE (30 MARKS)**

a) State and give a mathematical expression for the first law of thermodynamics (3 marks)

b) Classify the following properties of matter as either extensive or intensive (4 marks)

i. Pressure

ii. Density

iii. Internal energy

iv. Enthalpy

c) Explain why satisfying the first law of thermodynamics does not guarantee that a process will occur (3 marks)

d) Classify the following as isolated, closed or open system (4 marks)

i. Nitrogen and hydrogen reacting in a sealed tube to form ammonia

ii. A glass vial containing Sulphuric acid is broken inside water in a beaker

iii. Vacuum flask

iv. The Earth

e) Two Carnot engines operate with a temperature difference of 300 K between their hot and cold reservoirs. If engine A's hot reservoir is maintained at 1200 K, while that of engine B is maintained at 750 K, determine the most efficient engine. (3 marks)

f) Using second law of thermodynamics show that for a cyclic engine with no cold reservoir the conversion of all heat to equivalent work is non-spontaneous (4 marks)

g) Calculate the change in free energy when 11.21 $dm^3$ of a perfect gas at $0^oC$ and 760 mmHg pressure expands isothermally until its pressure is 190mmHg (3 marks)

h) The Critical temperature of methane and carbon dioxide are $-81.9^oC$ and $31.1^oC$. Which of these gases has stronger intermolecular forces and why? (3 marks)

i) Determine the entropy of the following reaction using information below (3 marks)

| **Substance** | **$S^o$($Jmol^{-1}K^{-1}$)** |
|---|---|
| $C_2H_{2(g)}$ | 210.82 |
| $H_{2(g)}$ | 140.59 |
| $C_2H_{4(g)}$ | 229.45 |

$C_2H_{2(g)} + H_{2(g)} \longrightarrow C_2H_{4(g)}$

**QUESTION TWO (20 MARKS)**

a) The standard molar enthalpy of formation of ammonia is -59.25kJ/mol. Using the heat capacity data given below, calculate the standard molar heat of formation of ammonia at 1000k (7 marks)

$C_pN_{2(g)}$ J/mol. k=26.98+(5.912×$10^{-3}$) T

$C_pNH_{3(g)}$ J/mol. k=25.89+(32.58×$10^{-3}$) T

$C_pH_{2(g)}$ J/mol. k=29.07-(0.837×$10^{-3}$) T

b) Define the following terms as used in thermodynamics

i. Specific heat capacity (2 marks)

ii. Molar heat capacity (2 marks)

c) What is the heat required to vaporize 1 mole of water ($H_2O_{(l)}$) at 25°C and 1 atmospheric pressure given $H_{vap}$ =70.68kJ/mol K, Cp of $H_2O_{(l)}$ =85.45J/mol K and Cp of $H_2O_{(g)}$ =25.75J/mol? (5 marks)

d) Describe the boundary conditions in;

i. Closed system (2 marks)

ii. Isolated system (2 marks)

**QUESTION THREE (20 MARKS)**

a) Sample of 1 mole of silver at 150 °C is placed in contact with 1mole of silver at 0 °C forming an isolated system at constant pressure. Assuming the specific heat capacity of silver is 28.85J/mol k, Calculate

i. The final temperature of both the silver samples (4 marks)

ii. $\Delta$S for the hot silver (2 marks)

iii. $\Delta$S for the cold silver (2 marks)

iv. The total $\Delta$S of the system (1 mark)

v. Is the process above spontaneous (1 mark)

b) Provide an expression for work done by a gas as it expands by volume $\Delta V$ against an external pressure $P_{ext.}$ (2 marks)

c) Give an expression for the change in internal energy of the system as a gas expands by volume $\Delta V$ against an external pressure $P_{ext}$ on absorbing q joules of heat. (3 marks)

d) A sample of gas changes in volume from 6 L to 8 L against an external pressure of 2.5 atm and simultaneously absorbs 1000 J of heat. Calculate the change in the internal energy of the system. (5 marks)

**QUESTION FOUR (20 MARKS)**

a) A 4 L sample of hydrogen gas at 15 atm and 25 °C is allowed to expand to a final pressure of 1atm. Calculate q, w, ΔU and ΔH if the gas expands adiabatically and reversibly given

$\frac{T_2}{T_1} = \frac{P_2}{P_1}^{\frac{\gamma-1}{\gamma}}$ and $\gamma = \frac{C_p}{C_v}$ (10 marks)

b) A certain gas expands from 250 mL to 750 mL very slowly at 25°C. If there is one mole of the gas in the chamber, calculate the work done when the gas behaves ideally (5 marks)

c) Given the following standard enthalpies of formation, calculate the standard enthalpy of combustion ($\Delta H^o_{\text{combustion}}$) of benzene at 298 k (5 marks)

| Compound | $\Delta H^o$f (kJ/mol k) |
|---|---|
| $CO_2$ | -393.51 |
| $C_6H_6$ | +48.7 |
| $H_2O$ | -285.83 |

**QUESTION FIVE (20 MARKS)**

a) State the Hess's law (2 marks)

b) Calculate the enthalpy of the reaction, $C_2H_{4(g)}+H_{2(g)} \longrightarrow C_2H_{6(g)}$ at 298 k using the information given below (4 marks)

$C_2H_{4(g)}+3O_{2(g)} \longrightarrow 2CO_{2(g)}+2H_2O_{(g)}$ ΔH=-1395kJ

$C_2H_{6(g)}+{}^{7}/_{2}O_{2(g)} \longrightarrow 2CO_{2(g)}+3H_2O_{(g)}$ ΔH=-1550kJ

$H_{2(g)}+{}^{1}/_{2}O_{2(g)} \longrightarrow H_2O_{(g)}$ ΔH=-243kJ

c) State and explain the physical concept of entropy and its variation with temperature (4 marks)

d) Using $Cv = \frac{dE}{dT}$ and $Cp = \frac{\delta q_p}{dT}$ show that for a perfect gas $C_p=C_v+R$ (6 marks)

e) Using the generalized expression for clausius inequality ($dU + pdV - TdS \leq 0$), derive an alternative criterion for spontaneity at constant temperature and pressure (4 marks)