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GAILLIMH

NATIONAL UNIVERSITY OF IRELAND
GALWAY

SEMESTER 2 (SUMMER) EXAMINATIONS 1998-99

3rd Year B.Sc. Unit EP314 (Repeat) : Thermodynamics

Experimental Physics

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Time allowed : TWO hours
Answer THREE questions

Q.1 (a) (i) State the Clausius principle (i.e. the version of the second law of thermodynamics in terms of entropy)

(ii) Justify the statement: "The change in entropy for a system which proceeds from state 1 to state 2 is independent of the path taken, i.e. whether the process is reversible or irreversible."

(b) (i) $1\ kg$ of water at $0\ ^{\circ}C$ is brought into contact with a large heat bath at $100\ ^{\circ}C$. When the water has reached $100\ ^{\circ}C$, what has been the change in entropy of the water, the heat bath, and the entire system?

(ii) If the water has been heated from $0\ ^{\circ}C$ to $100\ ^{\circ}C$ by first bringing it in contact with a heat bath at $50\ ^{\circ}C$ and then with one at $100\ ^{\circ}C$, what would have been the change in entropy of the entire system?

(iii) How would you make the process of heating the water to $100\ ^{\circ}C$ reversible ?

Q.2 (a) (i) Explain what the throttling (Joule-Thomson) effect is ? What quantity is conserved in this process ? Draw a graph of T vs. P for this process. Define the Joule-Thomson coefficient. Explain what the terms 'inversion curve' and 'maximum inversion temperature' mean and what is their physical significance. What is the Joule-Thomson coefficient for an ideal gas ?

(ii) How can the throttling process be used in the liquefaction of gases?

(b) One kilomole of an ideal gas undergoes a throttling process from 4 atm to 1 atm. The initial temperature of the gas is 50^{0}C. Determine

(i) The temperature change.

(ii) The work done on and the heat added to the gas.

(iii) Using the fact that $\Delta S = \int \delta Q/T$ find the entropy change ΔS of the gas. Comment on your result.

p.t.o.

Q.3 (a) (i) Explain briefly what a fuel cell is and give examples of three kinds of fuel cell.

(ii) Which kind of fuel cell is being developed as a prototype fuel cell engine for cars ? What percentage of its fuel is converted into useful work and how does this compare with the internal combustion engine?

(b) Consider a fuel cell operating at 298 K and 1 atm where hydrogen is the fuel used. The reaction is $2H_2 + O_2 \rightarrow 2H_2O$. Calculate the EMF and the efficiency of the cell assuming that the cell operates reversibly. Two electrons per water molecule are exchanged.

Note: ΔH is the enthalpy of formation of the compound from its elements at 298 K and 1 atm. S is the entropy of the state at this temperature and pressure. Remember that $\Delta G = -n_0F_0E$, where E = is the EMF of the cell.

	$S(JK^{-1}mol^{-1})$	$\Delta H(kJmol^{-1})$
O_2	205.04	0
H_2	130.57	0
H_2O (liquid)	69.95	-285.83

Q.4 (a) (i) Consider a system composed of two phases. What is the condition for equilibrium between the two phases in terms of the chemical potential and the Gibbs free energy per particle? How are these two quantities related ?

(ii) The Clausius-Clapeyron equation $dP/dT = \Delta S/\Delta V$ relates the slope of P against T for what ? To what do ΔS and ΔV refer? Rewrite ΔS in terms of the latent heat.

(iii) For the case of water and ice in equilibrium what is the sign of dP/dT? Explain how this sign comes about.

(b) The transition temperature of grey and white tin at a pressure of one atmosphere is 291 K; grey tin being the stable form below this temperature. The change in enthalpy for this transition is 2238 J mol^{-1}. The densities of grey and white tin are 5.75 and 7.3 g cm^{-3} respectively, and the atomic weight of tin is 118.7.

(i) Find dP/dT in atm/K at 1 atm.

(ii) Assuming that dP/dT remains constant over the pressure range find the transition temperature at 100 atm.

Q.5 Answer <u>two</u> of the following:

a. List the types of vacuum gauges necessary to cover the range of pressures from 10^{-2} torr to 10^{-11} torr, indicating the approximate range of each. Describe the operating principles and derive the equation for the McLeod gauge.

b. Define the terms throughput and conductance as used in the flow of compressible fluids. Derive the expression for the effective pumping speed S_e in a chamber connected by a pipe, of conductance C, to a pump of speed S_p.

c. Describe, using a diagram, the operation of a sputter ion vacuum pump and also describe a suitable roughing pump to be used in conjunction with it. Outline the properties and advantages of such a system, mentioning the argon instability.

<u>Constants</u>:

The specific heat capacity of water = 4190 J kg^{-1}°C^{-1}
$F_0 = 9.65 \times 10^4$ C mol^{-1}