Q1.(a) Define the term *standard enthalpy of formation*, $\Delta H_f^\ominus$

....

....

....

(3)

(b) Use the data in the table to calculate the standard enthalpy of formation of liquid methylbenzene, C_7H_8

Substance	C(s)	H_2(g)	C_7H_8(l)
Standard enthalpy of combustion, $\Delta H_c^\ominus$ /kJ mol^{-1}	–394	–286	–3909

$$7C(s) + 4H_2(g) \rightarrow C_7H_8(l)$$

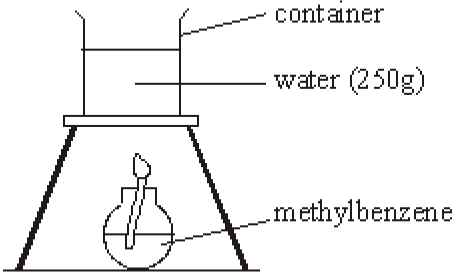
....

....

....

(3)

(c) An experiment was carried out to determine a value for the enthalpy of combustion of liquid methylbenzene using the apparatus shown in the diagram.



Burning 2.5 g of methylbenzene caused the temperature of 250 g of water to rise by 60°C. Use this information to calculate a value for the enthalpy of combustion of methylbenzene, C_7H_8

(The specific heat capacity of water is 4.18 J K^{-1} g^{-1}. Ignore the heat capacity of the container.)

....

....

....

....

(4)

(d) A 25.0 cm^3 sample of 2.00 mol dm^{-3} hydrochloric acid was mixed with 50.0 cm^3 of a 1.00 mol dm^{-3} solution of sodium hydroxide. Both solutions were initially at 18.0 °C.

After mixing, the temperature of the final solution was 26.5°C.

Use this information to calculate a value for the standard enthalpy change for the following reaction.

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

In your calculation, assume that the density of the final solution is 1.00 g cm^{-3} and that its specific heat capacity is the same as that of water. (Ignore the heat capacity of the container.)

....

....

....

....

(4)

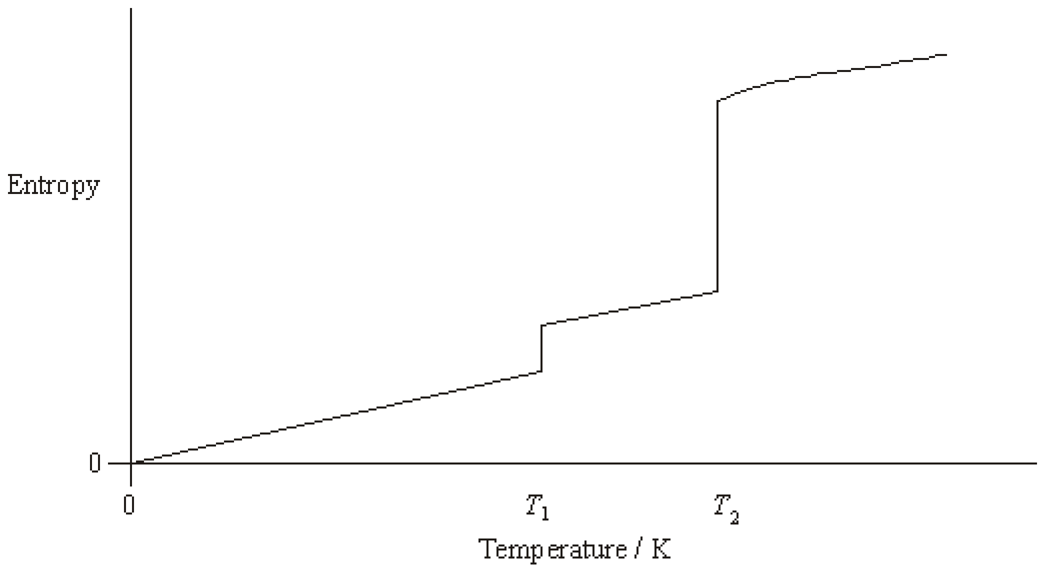
(e) Give **one** reason why your answer to part (d) has a much smaller experimental error than your answer to part (c).

....

....

(1)
(Total 15 marks)

Q2. The sketch graph below shows how the entropy of a sample of water varies with temperature.



(a) Suggest why the entropy of water is zero at 0 K.

....

(1)

(b) What change of state occurs at temperature T_1?

....

(1)

(c) Explain why the entropy change, ΔS, at temperature T_2 is much larger than that at temperature T_1.

....

....

....

(2)

(d) It requires 3.49 kJ of heat energy to convert 1.53 g of liquid water into steam at 373 K and 100 kPa.

(i) Use these data to calculate the enthalpy change, ΔH, when 1.00 mol of liquid water forms 1.00 mol of steam at 373 K and 100 kPa.

....

....

....

....

(ii) Write an expression showing the relationship between free-energy change, ΔG, enthalpy change, ΔH, and entropy change, ΔS.

....

(iii) For the conversion of liquid water into steam at 373 K and 100 kPa, $\Delta G = 0$ kJ mol^{-1}

Calculate the value of ΔS for the conversion of one mole of water into steam under these conditions. State the units.

(If you have been unable to complete part (d)(i) you should assume that $\Delta H = 45.0$ kJ mol^{-1}. This is not the correct answer.)

Calculation ....

....

....

Units ....

(6)
(Total 10 marks)

Q3. Methanol, CH_3OH, is a convenient liquid fuel.

(a) An experiment was conducted to determine the enthalpy of combustion of liquid methanol. The energy obtained from burning 2.12 g of methanol was used to heat 150 g of water. The temperature of the water rose from 298 K to 362 K. (The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

(i) Define the term *standard enthalpy of combustion*.

(ii) Use the data above to calculate a value for the enthalpy of combustion of one mole of liquid methanol.

(7)

(b) Methanol can be synthesised from methane and steam by a process that occurs in two stages.

Stage 1 $CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H^\ominus = +206\ \text{kJ mol}^{-1}$

Stage 2 $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $\Delta H^\ominus = -91\ \text{kJ mol}^{-1}$

(i) Explain why, in *Stage 1*, a higher yield of hydrogen and carbon monoxide is **not** obtained if the pressure is increased.

(ii) *Stage 2* is carried out at a compromise temperature of 500K. By considering what would happen at higher and lower temperatures, explain why 500 K is considered to be a compromise for *Stage 2*.

(5)

(c) The standard enthalpies of combustion of carbon monoxide and of hydrogen are –283 kJ mol^{-1} and –286 kJ mol^{-1}, respectively. Use these data and the enthalpy change for *Stage 2* to calculate a value for the standard enthalpy of combustion of gaseous methanol.

(3)

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

....

(Total 15 marks)