MEGA LECTURE

A-LEVEL CHEMISTRY

ASSESSMENT POINT 1

PAPER 1

(TOPICS 10 and 11)

Answer all questions

Max 80 marks

Name ……
Mark ……../80 ……..% Grade ……

1. This question is about bond dissociation enthalpies and their use in the calculation of enthalpy changes.

(a) Define *bond dissociation enthalpy* as applied to chlorine.

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(b) Explain why the enthalpy of atomisation of chlorine is exactly half the bond dissociation enthalpy of chlorine.

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(c) The bond dissociation enthalpy for chlorine is +242 kJ mol $^{-1}$ and that for fluorine is +158 kJ mol $^{-1}$. The standard enthalpy of formation of ClF(g) is 56 kJ mol $^{-1}$.

(i) Write an equation, including state symbols, for the reaction that has an enthalpy change equal to the standard enthalpy of formation of gaseous ClF

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(ii) Calculate a value for the bond enthalpy of the Cl – F bond.

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(iii) Calculate the enthalpy of formation of gaseous chlorine trifluoride, ClF_3(g). Use the bond enthalpy value that you obtained in part (c)(ii).

(If you have been unable to obtain an answer to part (c)(ii), you may assume that the Cl – F bond enthalpy is +223 kJ mol $^{-1}$. This is **not** the correct value.)

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(iv) Explain why the enthalpy of formation of $ClF_3(g)$ that you calculated in part (c)(iii) is likely to be different from a data book value.

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(d) Suggest why a value for the Na – Cl bond enthalpy is **not** found in any data book.

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(Total 11 marks)

2. Ammonia can be manufactured by the Haber Process.

The equation for the reaction that occurs is shown below.

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

(a) The table below contains some bond enthalpy data.

	N ≡ N	H–H	N–H
Mean bond enthalpy / kJ mol^{-1}	944	436	388

(i) Use data from the table to calculate a value for the enthalpy of formation for one mole of ammonia.

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(ii) A more accurate value for the enthalpy of formation of ammonia is
–46 kJ mol^{-1}.
Suggest why your answer to part (a) (i) is different from this value.

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(b) The table below contains some entropy data.

	$H_2(g)$	$N_2(g)$	$NH_3(g)$
$S\theta$ / J K^{-1} mol^{-1}	131	192	193

Use these data to calculate a value for the entropy change, with units, for the formation of one mole of ammonia from its elements.

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(c) The synthesis of ammonia is usually carried out at about 800 K.

(i) Use the Δ*H* value of –46 kJ mol^{-1} and your answer from part (b) to calculate a value for Δ*G*, with units, for the synthesis at this temperature.
(If you have been unable to obtain an answer to part (b), you may assume that the entropy change is –112 J K^{-1} mol^{-1}. This is not the correct answer.)

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(ii) Use the value of Δ*G* that you have obtained to comment on the feasibility of the reaction at 800 K.

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(Total 11 marks)

3. When a mixture of 0.345 mol of PCl_3 and 0.268 mol of Cl_2 was heated in a vessel of fixed volume to a constant temperature, the following reaction

reached equilibrium.

$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \quad \Delta H = -93 \text{ kJ mol}^{-1}$

At equilibrium, 0.166 mol of PCl_5 had been formed and the total pressure was 225 kPa.

(a) (i) Calculate the number of moles of PCl_3 and of Cl_2 in the equilibrium mixture.

Moles of PCl_3 .....

Moles of Cl_2 .....

(ii) Calculate the total number of moles of gas in the equilibrium mixture.

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(b) Calculate the mole fraction and the partial pressure of PCl_3 in the equilibrium mixture.

Mole fraction of PCl_3 .....

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Partial pressure of PCl_3 .....

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(c) (i) Write an expression for the equilibrium constant, K_p, for this equilibrium.

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(ii) The partial pressures of Cl_2 and PCl_5 in the equilibrium mixture were 51.3 kPa and 83.6 kPa, respectively, and the total pressure remained at 225 kPa. Calculate the value of K_p at this temperature and state its units.

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(d) State the effect on the mole fraction of PCl_3 in the equilibrium mixture if

(i) the volume of the vessel were to be increased at a constant temperature,

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(ii) the temperature were to be increased at constant volume.

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(Total 12 marks)

4. (a) Define the term **electron affinity** for chlorine.

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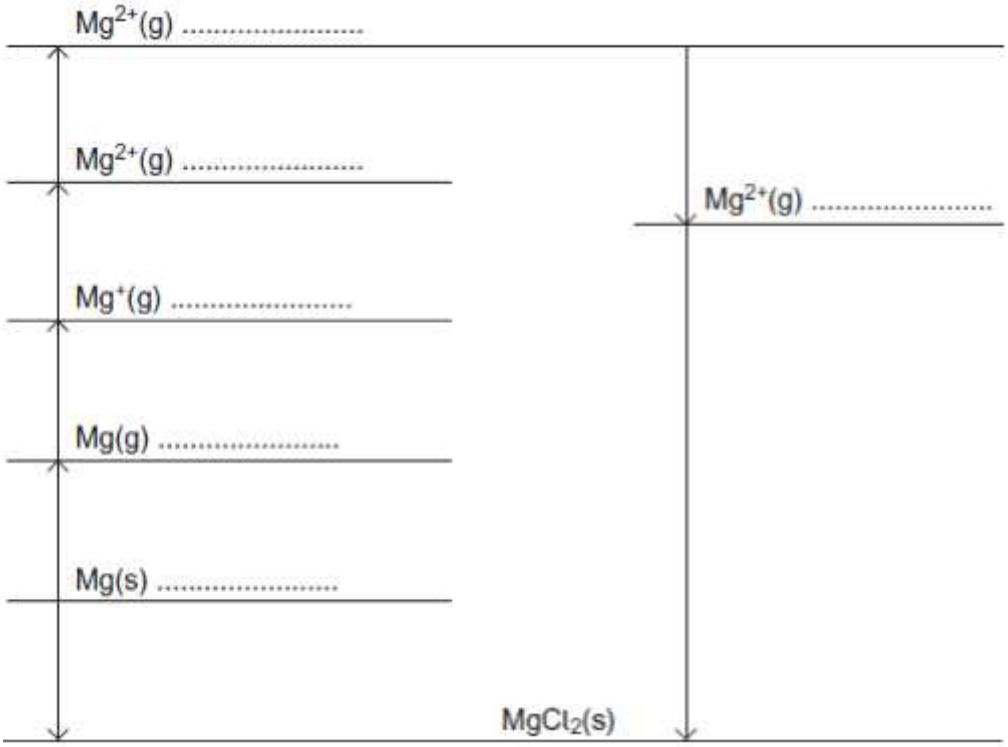
(b) Complete this Born Haber cycle for magnesium chloride by giving the missing species on the dotted lines. Include state symbols where appropriate.

The energy levels are **not** drawn to scale.



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(c) **Table 1** contains some enthalpy data.

Table 1

	Enthalpy change / kJ mol $^{-1}$
Enthalpy of atomisation of magnesium	+150
Enthalpy of atomisation of chlorine	+121
First ionisation energy of magnesium	+736
Second ionisation energy of magnesium	+1450
Enthalpy of formation of magnesium chloride	642

Lattice enthalpy of formation of magnesium chloride	2493

Use your Born – Haber cycle from part (b) and data from **Table 1** to calculate a value for the electron affinity of chlorine.

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(d) **Table 2** contains some more enthalpy data.

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of hydration of Mg^{2+} ions	−1920
Enthalpy of hydration of Na^{+} ions	−406
Enthalpy of hydration of Cl^{-} ions	364

(i) Explain why there is a difference between the hydration enthalpies of the magnesium and sodium ions.

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(ii) Use data from **Table 1** and **Table 2** to calculate a value for the enthalpy change when one mole of magnesium chloride dissolves in water.

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(Total 15 marks)

5. When potassium nitrate (KNO_3) dissolves in water the value of the enthalpy change
ΔH = +34.9 kJ mol^{-1} and the value of the entropy change ΔS = +117 J K^{-1} mol^{-1}.

(a) Write an equation, including state symbols, for the process that occurs when potassium nitrate dissolves in water.

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(b) Suggest why the entropy change for this process is positive.

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(c) Calculate the temperature at which the free-energy change, ΔG, for this process is zero.

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(d) (i) Deduce what happens to the value of ΔG when potassium nitrate dissolves in water at a temperature lower than your answer to part (c).

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(ii) What does this new value of Δ*G* suggest about the dissolving of potassium nitrate at this lower temperature?

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(Total 7 marks)

6. Hydrogen can be manufactured from the reaction of steam with methane.

$$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g)$$

(a) The table contains some enthalpy of formation and entropy data.

Substance	$\Delta H_f^{\ominus}$ / kJ mol $^{-1}$	$S^{\ominus}$ / J K $^{-1}$ mol $^{-1}$
$CH_4(g)$	−75	186
$H_2O(g)$	−242	189
$CO(g)$	111	198
$H_2(g)$	−0	131
$CO_2(g)$	394	214

(i) Use data from the table to calculate the enthalpy change, ΔH, for the reaction of steam with methane.

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(ii) Use data from the table to calculate the entropy change, ΔS, for the reaction of steam with methane.

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(b) Use your values of Δ*H* and Δ*S* from parts (a)(i) and (a)(ii) to calculate the temperature above which this reaction is feasible.

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(c) The temperature used for this manufacture of hydrogen is usually about 1300 K.

Suggest **one** reason, other than changing the position of equilibrium, why this temperature is used rather than the value that you calculated in part (b).

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(d) Hydrogen can also be obtained by reaction of carbon monoxide with steam.

$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$ $\Delta H = -41$ kJ mol^{-1}, $\Delta S = -42$ J K^{-1} mol^{-1}

(i) Explain, using a calculation, why this reaction should **not** occur at 1300 K.

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(ii) Explain how the conditions for the reaction could be changed to allow this reaction to take place.

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(Total 15 marks)

7. Consider the following process that represents the melting of ice

$H_2O(s) \rightarrow H_2O(l)$ $\quad H^{\ominus} = +6.03 \text{ kJ mol}^{-1}$, $\quad S^{\ominus} = +22.1 \text{ J K}^{-1} \text{ mol}^{-1}$

(a) State the meaning of the symbol $^{\ominus}$ in $H^{\ominus}$.

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(b) Use your knowledge of bonding to explain why $H^{\ominus}$ is positive for this process.

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(c) Calculate the temperature at which $G^{\ominus} = 0$ for this process. Show your working.

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(d) The freezing of water is an exothermic process. Give **one** reason why the temperature of a sample of water can stay at a constant value of 0 °C when it freezes.

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(e) Pure ice can look pale blue when illuminated by white light. Suggest an explanation for this observation.

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