

Q1. This question is about magnesium oxide. Use data from the table below, where appropriate, to answer the following questions.

	$\Delta H^\ominus / \text{kJ mol}^{-1}$
First electron affinity of oxygen (formation of $\text{O}^-(\text{g})$ from $\text{O}(\text{g})$)	-142
Second electron affinity of oxygen (formation of $\text{O}^{2-}(\text{g})$ from $\text{O}^-(\text{g})$)	+844
Atomisation enthalpy of oxygen	+248

(a) Define the term *enthalpy of lattice dissociation*.

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(3)

(b) In terms of the forces acting on particles, suggest **one** reason why the first electron affinity of oxygen is an exothermic process.

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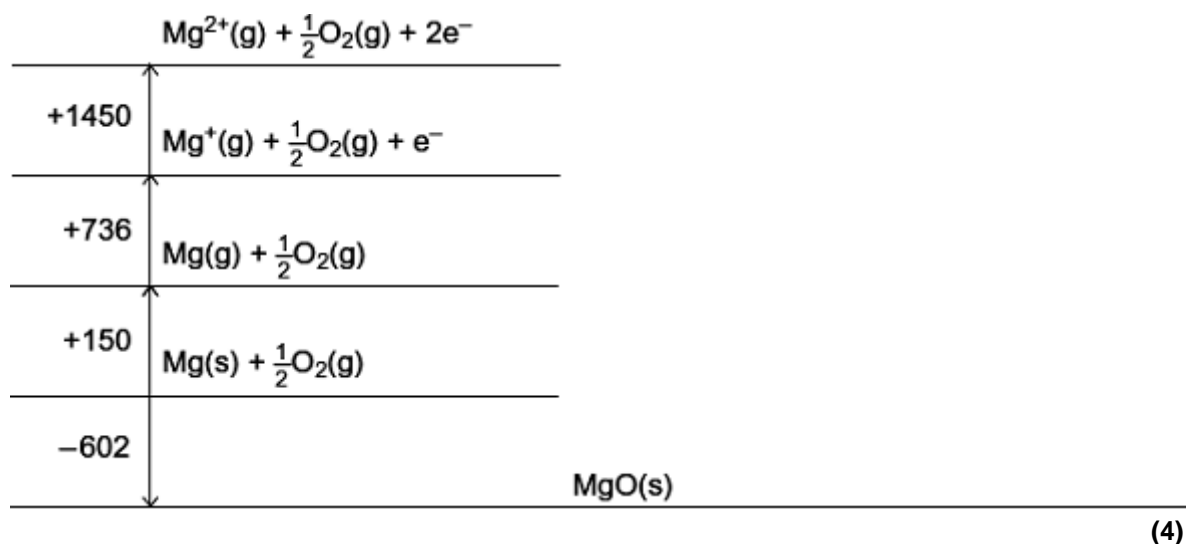
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(1)

(c) Complete the Born–Haber cycle for magnesium oxide by drawing the missing energy levels, symbols and arrows.
The standard enthalpy change values are given in kJ mol^{-1} .



(d) Use your Born–Haber cycle from part (c) to calculate a value for the enthalpy of lattice dissociation for magnesium oxide.

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(e) The standard free-energy change for the formation of magnesium oxide from magnesium and oxygen, $\Delta G_f^\ominus = -570 \text{ kJ mol}^{-1}$. Suggest **one** reason why a sample of magnesium appears to be stable in air at room temperature, despite this negative value for ΔG_f^\ominus .

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(1)

(f) Use the value of ΔG_f^\ominus given in part (e) and the value of ΔH_f^\ominus from part (c) to calculate a value for the entropy change ΔS^\ominus when one mole of magnesium oxide is formed from magnesium and oxygen at 298 K. Give the units of ΔS^\ominus .

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(g) In terms of the reactants and products and their physical states, account for the sign of the entropy change that you calculated in part (f).

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(Total 16 marks)

Q2. When potassium nitrate (KNO_3) dissolves in water the value of the enthalpy change $\Delta H = +34.9 \text{ kJ mol}^{-1}$ and the value of the entropy change $\Delta S = +117 \text{ J K}^{-1} \text{ mol}^{-1}$.

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

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(1)

(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 ΔG suggest about the dissolving of potassium nitrate at this lower temperature?

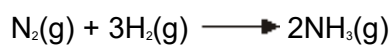
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(Total 7 marks)

Q3. Ammonia can be manufactured by the Haber Process.

The equation for the reaction that occurs is shown below.



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

	$\text{N} \equiv \text{N}$	$\text{H}-\text{H}$	$\text{N}-\text{H}$
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.

	$\text{H}_2(\text{g})$	$\text{N}_2(\text{g})$	$\text{NH}_3(\text{g})$
$S_e / \text{J K}^{-1} \text{ mol}^{-1}$	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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(3)

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

- (i) Use the ΔH value of -46 kJ mol^{-1} and your answer from part (b) to calculate a value for ΔG , 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 $-112 \text{ J K}^{-1} \text{ mol}^{-1}$. This is not the correct answer.)

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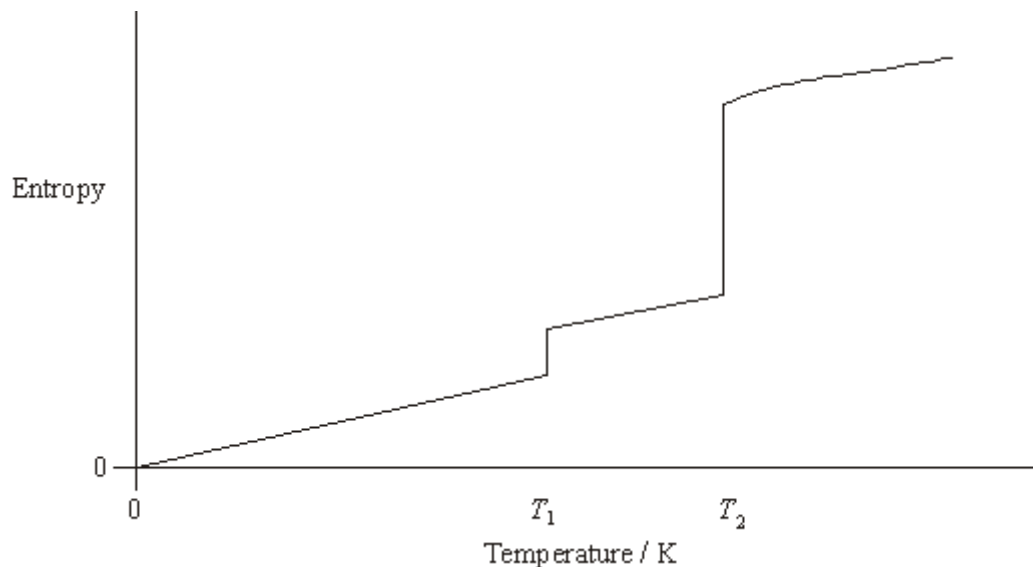
- (ii) Use the value of ΔG that you have obtained to comment on the feasibility of the reaction at 800 K.

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(1)

(Total 11 marks)

Q4. 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.

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(1)

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

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(1)

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

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(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.

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

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

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 $\Delta H = 45.0 \text{ kJ mol}^{-1}$. This is not the correct answer.)

Calculation

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Units

(6)
(Total 10 marks)

- Q5.** The balance between enthalpy change and entropy change determines the feasibility of a reaction. The table below contains enthalpy of formation and entropy data for some elements and compounds.

	$\text{N}_2(\text{g})$	$\text{O}_2(\text{g})$	$\text{NO}(\text{g})$	$\text{C}(\text{graphite})$	$\text{C}(\text{diamond})$
$\Delta H_f^\circ/\text{kJ mol}^{-1}$	0	0	+90.4	0	+1.9
$S^\circ/\text{J K}^{-1} \text{ mol}^{-1}$	192.2	205.3	211.1	5.7	2.4

- (a) Explain why the entropy value for the element nitrogen is much greater than the entropy value for the element carbon (graphite).

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- (b) Suggest the condition under which the element carbon (diamond) would have an entropy value of zero.

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- (c) Write the equation that shows the relationship between ΔG , ΔH and ΔS for a reaction.

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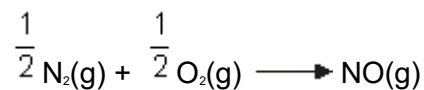
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- (d) State the requirement for a reaction to be feasible.

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(1)

- (e) Consider the following reaction that can lead to the release of the pollutant NO into the atmosphere.



Use data from the table above to calculate the minimum temperature above which this reaction is feasible.

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- (f) At temperatures below the value calculated in part (e), decomposition of NO into its elements should be spontaneous. However, in car exhausts this decomposition reaction does **not** take place in the absence of a catalyst. Suggest why this spontaneous decomposition does **not** take place.

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(1)

- (g) A student had an idea to earn money by carrying out the following reaction.



Use data from the table above to calculate values for ΔH and ΔS^\ominus for this reaction. Use these values to explain why this reaction is **not** feasible under standard pressure at any temperature.

ΔH^\ominus

ΔS^\ominus

Explanation

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(3)

(Total 14 marks)