Thermodynamics and Kinetics Exam

Assessment Week 1

Name_____

Total Marks 71
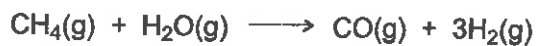# Time Allowed: 75 Minutes

1 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	$\Delta H^{\ominus}_f$ / 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.

....

....

....

....

....

....

....

(3)

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

....

....

....

....

....

(2)

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

....

....

....

....

....

....

....

....

(4)

(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).

....

....

(1)

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

$CO(g) + H_2O(g) \longrightarrow CO_2(g) + H_2(g)$ $\Delta H = -41$ 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.

....

....

....

....

....

....

....

(3)

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

....

....

....

....

....

(2)
(Total 15 marks)

2 This table contains some values of lattice dissociation enthalpies.

Compound	$MgCl_2$	$CaCl_2$	MgO
Lattice dissociation enthalpy / kJ mol^{-1}	2493	2237	3889

(a) Write an equation, including state symbols, for the reaction that has an enthalpy change equal to the lattice dissociation enthalpy of magnesium chloride.

....

(1)

(b) Explain why the lattice dissociation enthalpy of magnesium chloride is greater than that of calcium chloride.

....

....

....

....

(Extra space) ....

....

(2)

(c)   Explain why the lattice dissociation enthalpy of magnesium oxide is greater than that of magnesium chloride.

....

....

....

....

(Extra space) ....

....

(2)

(d)   When magnesium chloride dissolves in water, the enthalpy of solution is -155 kJ mol^{-1}. The enthalpy of hydration of chloride ions is -364 kJ mol^{-1}.

Calculate the enthalpy of hydration of magnesium ions.

....

....

....

....

....

....

(Extra space) ....

....

(3)

(e)   Energy is released when a magnesium ion is hydrated because magnesium ions attract water molecules.

Explain why magnesium ions attract water molecules.
You may use a labelled diagram to illustrate your answer.

....

....

....

....

....

....

(2)

(f)   Suggest why a value for the enthalpy of solution of magnesium oxide is **not** found in any data books.

....

....

....

(1)
(Total 11 marks)

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

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

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

....

....

....

....

....

....

(3)

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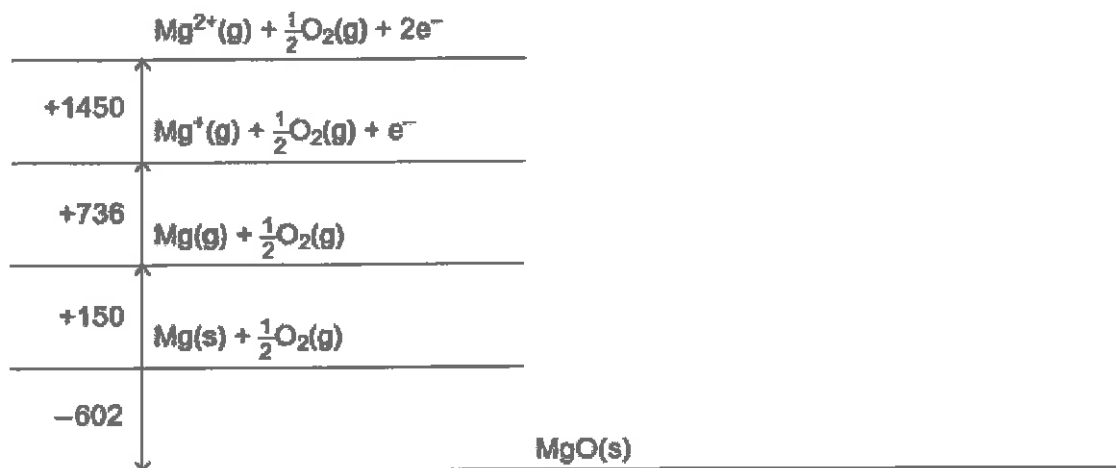
....

....

(Extra space) ....

....

(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}.

$$Mg^{2+}(g) + \tfrac{1}{2}O_2(g) + 2e^-$$

+1450 $Mg^+(g) + \tfrac{1}{2}O_2(g) + e^-$

+736 $Mg(g) + \tfrac{1}{2}O_2(g)$

+150 $Mg(s) + \tfrac{1}{2}O_2(g)$

−602

$MgO(s)$

(4)

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

....

....

....

....

(2)

(e) The standard free-energy change for the formation of magnesium oxide from magnesium and oxygen, $\Delta G_f^{\ominus} = -570$ 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 $\Delta G_f^{\ominus}$.

....

....

(Extra space) ....

....

(1)

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

....

....

....

....

....

(Extra space) ....

....

(3)

(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).
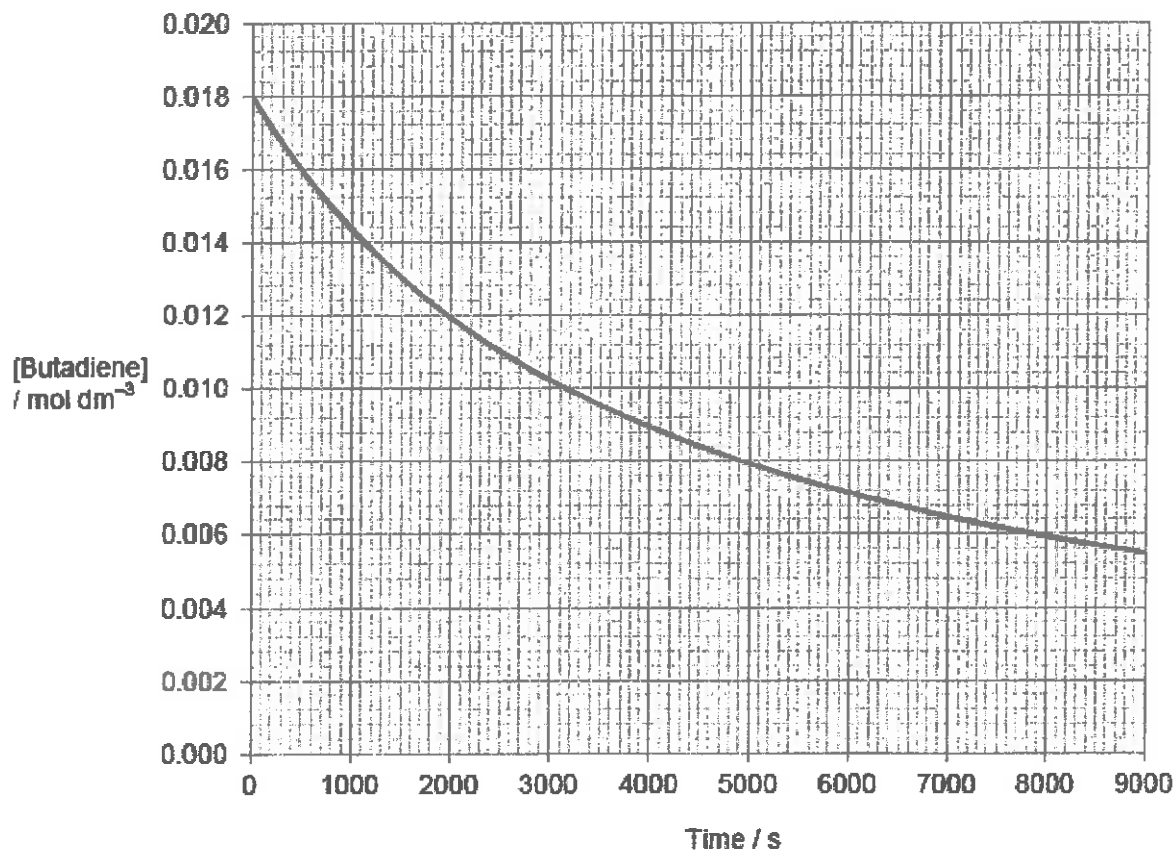
....

....

....

....

(2)
(Total 16 marks)

4 Butadiene dimerises according to the equation

$$2C_4H_6 \longrightarrow C_8H_{12}$$

The kinetics of the dimerisation are studied and the graph of the concentration of a sample of butadiene is plotted against time. The graph is shown below.

(a) Draw a tangent to the curve when the concentration of butadiene is 0.0120 mol dm^{-3}.

(1)

(b) The initial rate of reaction in this experiment has the value 4.57×10^{-6} mol dm^{-3} s^{-1}.

Use this value, together with a rate obtained from your tangent, to justify that the order of the reaction is 2 with respect to butadiene.

....

....

....

....

....

....

....

....

....

....

(5)
(Total 6 marks)

5 The initial rate of the reaction between two gases **P** and **Q** was measured in a series of experiments at a constant temperature. The following rate equation was determined.

$$\text{rate} = k[P]^2[Q]$$

(a) Complete the table of data below for the reaction between **P** and **Q**.

Experiment	Initial [P] /mol dm^{-3}	Initial [Q] /mol dm^{-3}	Initial rate /mol dm^{-3} s^{-1}
1	0.20	0.30	$1.8 = 10^{-3}$
2	0.40	0.60	
3	0.60		$5.4 = 10^{-3}$
4		0.90	$12.2 = 10^{-3}$

(Space for working) ....

....

....

....

....
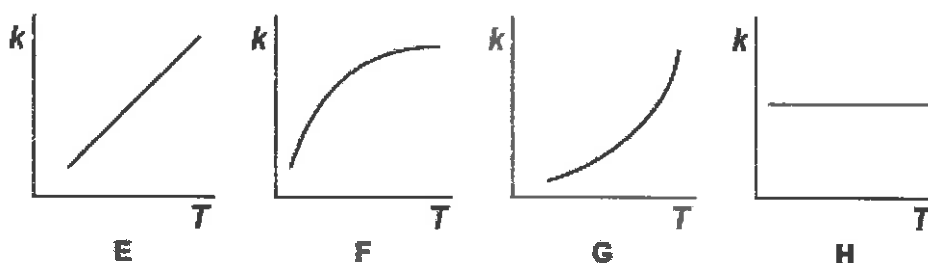
(3)

(b) Use the data from Experiment **1** to calculate a value for the rate constant k and deduce its units.

Calculation ....

....

....

....

....

Units ....

....

(3)

(c) Consider the graphs **E, F, G** and **H** below.

Write in the box below the letter of the graph that shows how the rate constant *k* varies with temperature.

(1)
(Total 7 marks)

6 Ethanol can be oxidised by acidified potassium dichromate(VI) to ethanoic acid in a two-step process.

ethanol ⟶ ethanal ⟶ ethanoic acid

(a) In order to ensure that the oxidation to ethanoic acid is complete, the reaction is carried out under reflux.

Describe what happens when a reaction mixture is refluxed and why it is necessary, in this case, for complete oxidation to ethanoic acid.

....

....

....

....

....

....

....

....

(3)

(b) Write a half-equation for the overall oxidation of ethanol into ethanoic acid.

....

(1)

(c) The boiling points of the organic compounds in a reaction mixture are shown in the following table.

Compound	ethanol	ethanal	ethanoic acid
Boiling point / °C	78	21	118

Use these data to describe how you would obtain a sample of ethanal from a mixture of these three compounds. Include in your answer a description of the apparatus you would use and how you would minimise the loss of ethanal. Your description of the apparatus can be either a description in words or a labelled sketch.

....

....

....

....

....

....

....

....

(5)

(d) Use your knowledge of structure and bonding to explain why it is possible to separate ethanal in this way.

....

....

....

....

....

(2)

(e)   A student obtained a sample of a liquid using the apparatus in part **(c)**.

Describe how the student could use chemical tests to confirm that the liquid contained ethanal and did **not** contain ethanoic acid.

....

....

....

....

....

....

....

....

(5)
(Total 16 marks)