OCR
Oxford Cambridge and RSA

Monday 19 June 2017 – Morning

A2 GCE CHEMISTRY A

F325/01 Equilibria, Energetics and Elements

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry A* (inserted)

Other materials required:
- Scientific calculator

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found inside this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means, for example, you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **100**.
- This document consists of **20** pages. Any blank pages are indicated.

Answer **all** the questions.

1 Lattice enthalpies can be calculated indirectly using Born–Haber cycles.

Table 1.1 shows enthalpy changes that can be used to calculate the lattice enthalpy of magnesium bromide, $MgBr_2$.

Letter	Enthalpy change	Energy / $kJ\,mol^{-1}$
A	atomisation of magnesium	+146
B	1st ionisation energy of magnesium	+738
C	2nd ionisation energy of magnesium	+1451
D	atomisation of bromine	+112
E	1st electron affinity of bromine	–325
F	formation of magnesium bromide	–524
G	lattice enthalpy of magnesium bromide	

Table 1.1

(a) Define the term *lattice enthalpy*.

....

....

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.... **[2]**

(b) Lattice enthalpies are exothermic.

Explain why it is difficult to predict whether the lattice enthalpy of magnesium bromide would be more or less exothermic than the lattice enthalpy of sodium chloride.

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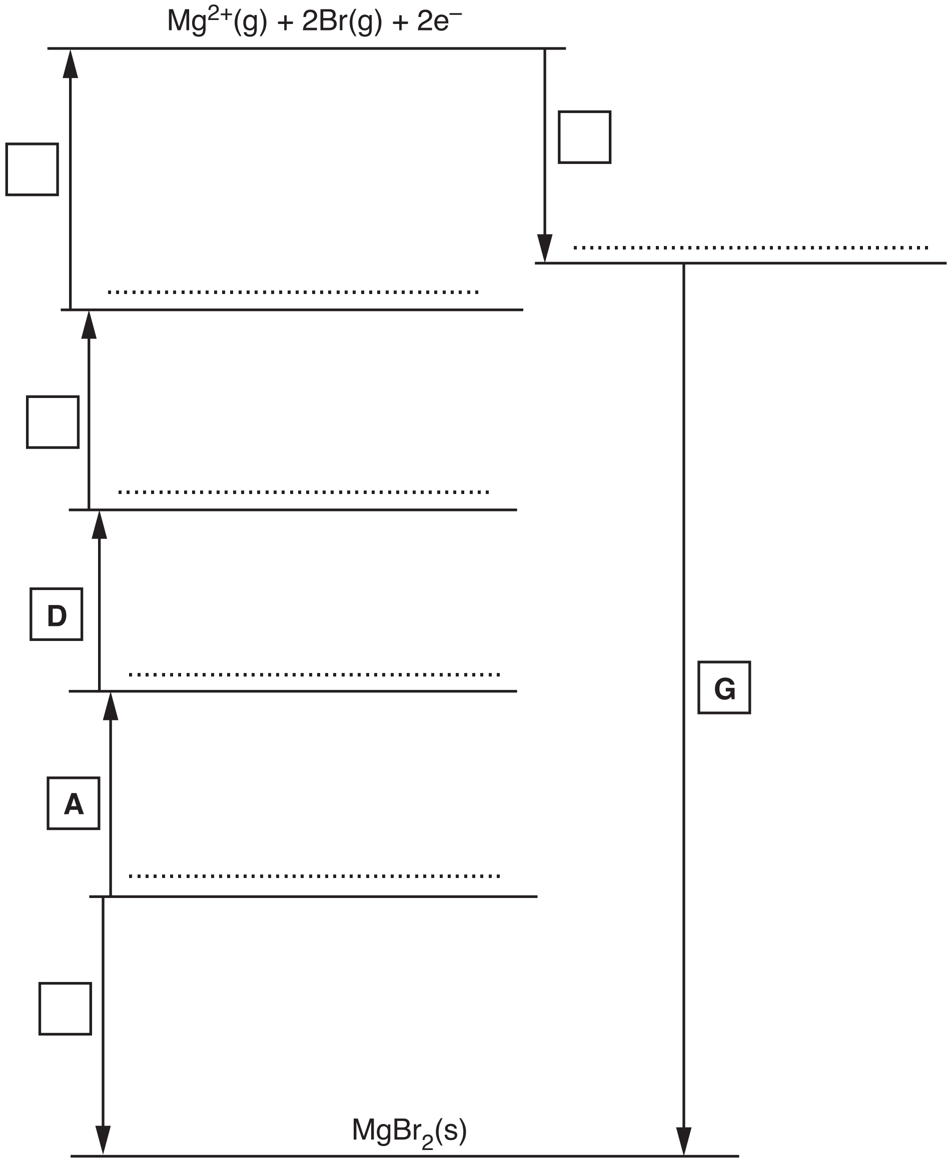
.... **[3]**

(c) The Born–Haber cycle below links the lattice enthalpy of magnesium bromide with the enthalpy changes in **Table 1.1**.

(i) Add the correct letters from **Table 1.1** in the four empty boxes and write the correct species on the five dotted lines.



[6]

(ii) Calculate the lattice enthalpy of magnesium bromide.

lattice enthalpy = ... kJ mol^{-1} **[2]**

[Total: 13]

2 Entropy changes and free energy changes can be used to predict the feasibility of processes.

(a) Three processes are given below.

For each process, predict and explain whether the entropy change, ΔS, would be positive or negative.

- The melting of iron.

  ΔS: positive or negative ....

  explanation ....

  ....

  ....

- The reaction of magnesium with dilute sulfuric acid.

  ΔS: positive or negative ....

  explanation ....

  ....

  ....

- The complete combustion of ethane:

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l)$$

  ΔS: positive or negative ....

  explanation ....

  ....

  ....

[3]

(b) Ammonia can be oxidised as shown in the equation below.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

At 450 °C, ΔH = –907 kJ mol^{-1} and ΔG = –1041 kJ mol^{-1}.

Calculate the standard entropy change, ΔS, in J K^{-1} mol^{-1}, for this reaction.

Show all your working.

ΔS = ... J K^{-1} mol^{-1} **[2]**

(c) A reaction is **not** feasible at low temperatures but is feasible at high temperatures.

Deduce the signs of ΔH and ΔS for the reaction and explain why the feasibility changes with temperature.

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.... **[3]**

[Total: 8]

3 Nitrogen monoxide, NO, and hydrogen, H_2, react together.

The rate equation is shown below:

$$\text{rate} = k[\text{NO(g)}]^2\,[\text{H}_2\text{(g)}]$$

(a) What are the orders of reaction shown below?

Order with respect to NO(g): ....

Order with respect to H_2(g): ....

Overall order of reaction: ....
[1]

(b) Predict what would happen to the initial rate of the reaction between NO and H_2 for the following change in concentrations.

The concentrations of NO(g) and H_2(g) are **both** increased by five times.

.... **[1]**

(c) Nitrogen monoxide and hydrogen are reacted together. The initial concentrations and initial rate are shown below.

[NO(g)] / mol dm^{-3}	3.24×10^{-3}
[H_2(g)] / mol dm^{-3}	5.45×10^{-2}
initial rate / mol dm^{-3} s^{-1}	4.34×10^{-2}

Calculate the rate constant, *k*, for this reaction. State the units, if any.

Give your answer to **three** significant figures and in standard form.

k = ... units .... **[3]**

(d) Complete the table below to show the effect on the reaction rate and the rate constant, *k*, of the following changes in conditions.

Use the words **increases**, **decreases** or **none**.

Change	**Effect on reaction rate**	**Effect on rate constant**
Increase in pressure		
Increase in temperature		

[2]

(e) This reaction between NO(g) and H_2(g) takes place by a two-step mechanism.

The rate equation is shown below:

$$\text{rate} = k[\text{NO(g)}]^2\,[\text{H}_2\text{(g)}]$$

- In the mechanism, **step 1** is much slower than **step 2**.
- The equation for **step 2** is shown below.

Write the equations for **step 1** and the **overall reaction**.

step 1: ....

step 2: $H_2(g) + N_2O(g) \rightarrow N_2(g) + H_2O(g)$

overall reaction: ....
[2]

[Total: 9]

4 This question is about the chemistry of different transition elements.

(a) Vanadium, V, is a typical transition element in the d-block of the Periodic Table. In its compounds and ions, vanadium has several common oxidation numbers, +2, +3, +4 and +5.

(i) Show that vanadium is both a *d-block element* and *transition element*.

In your answer, include full electron configurations of vanadium in its 0 and +2 oxidation states.

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.... **[4]**

(ii) An acidified solution containing VO_3^- ions reacts with zinc metal in a redox reaction. The resulting solution contains Zn^{2+} ions and V^{2+} ions.

The unbalanced half-equations are shown below.

Balance these half-equations and construct an overall equation for this reaction.

Half-equation 1: $VO_3^- + H^+ + e^- \rightarrow V^{2+} + H_2O$

Half-equation 2: $Zn \rightarrow Zn^{2+} + e^-$

Overall equation: ....

[3]

(b) Platin, $Pt(NH_3)_2Cl_2$, is an uncharged complex of platinum(II) that has two stereoisomers. One of these stereoisomers is used in chemotherapy for the treatment of some cancers.

(i) Explain why platin has no charge.

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.... **[1]**

(ii) Draw labelled diagrams of the two stereoisomers of platin, showing clearly the atoms involved in bonding, and describe the bonding involving Pt with its ligands.

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.... **[3]**

(iii) Describe the action of one of the stereoisomers of platin in the treatment of cancer patients.

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.... **[1]**

(c) Aqueous cobalt(II) ions are reacted with aqueous sodium hydroxide and with concentrated hydrochloric acid.

Describe these reactions. Include colours of the cobalt-containing species, ionic equations and the types of reaction taking place.

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.... **[7]**

[Total: 19]

5 This question is about acids, bases and buffer solutions.

(a) Ethanoic acid, CH_3COOH, and propanoic acid, C_2H_5COOH, are weak Brønsted–Lowry acids.

The acid dissociation constants, K_a, of the two acids are shown below.

Acid	**K_a / mol dm^{-3}**
CH_3COOH	1.70×10^{-5}
C_2H_5COOH	1.30×10^{-5}

(i) Explain the term *weak acid*.

....

.... **[1]**

(ii) Write the expression for the acid dissociation constant, K_a, of ethanoic acid.

[1]

(iii) Calculate the pH of a 2.85×10^{-2} mol dm^{-3} solution of C_2H_5COOH.

Give your answer to **two** decimal places.

pH = ... **[2]**

(iv) Ethanoic acid is mixed with propanoic acid. An acid–base equilibrium is set up.

Complete the equation for the equilibrium.

Label the conjugate acid–base pairs using the labels **acid 1**, **base 1**, **acid 2**, **base 2**.

C_2H_5COOH + CH_3COOH $\rightleftharpoons$ .... + ...

....

[2]

(b) Barium hydroxide, $Ba(OH)_2$, is a strong Brønsted–Lowry base.

A student prepares 250.0 cm^3 of 0.1250 mol dm^{-3} barium hydroxide.

(i) Explain what is meant by the term *Brønsted–Lowry base*.

....

.... **[1]**

(ii) Calculate the mass of $Ba(OH)_2$ that the student would need to weigh on a **two** decimal place balance to prepare 250.0 cm^3 of 0.1250 mol dm^{-3} $Ba(OH)_2$.

mass = ... (g) **[3]**

(iii) Calculate the pH of a 0.1250 mol dm^{-3} solution of $Ba(OH)_2$.

Give your answer to **two** decimal places.

pH = ... **[3]**

(c) The student attempts to prepare a buffer solution by mixing 200 cm^3 of 0.324 mol dm^{-3} C_2H_5COOH with 100 cm^3 of the 0.1250 mol dm^{-3} $Ba(OH)_2$ prepared in **(b)**.

The equation for the reaction that takes place is shown below.

$$2C_2H_5COOH(aq) + Ba(OH)_2(aq) \rightarrow (C_2H_5COO)_2Ba(aq) + 2H_2O(l)$$

Explain whether the student was successful in preparing a buffer solution.

Include all reasoning and any relevant calculations.

.... **[4]**

(d) Blood contains a mixture of carbonic acid, H_2CO_3, and hydrogencarbonate ions, HCO_3^-.

Explain how the carbonic acid–hydrogencarbonate mixture acts as a buffer.

In your answer include the equation for the equilibrium in this buffer solution and explain how this equilibrium system is able to control blood pH.

.... **[5]**

[Total: 22]

6 Ammonia can be manufactured from nitrogen and hydrogen gases in the Haber process.
The equilibrium is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

(a) Write an expression for K_c for this equilibrium.

[1]

(b) A chemist carries out a series of experiments to investigate the conversion of nitrogen and hydrogen into ammonia under different conditions.

- The chemist mixes together 10.40 mol N_2 and 22.50 mol H_2 and pressurises the gases so that the total gas volume is 5.00 dm^3.
- The mixture is allowed to reach equilibrium at constant temperature and without changing the total gas volume.
- The equilibrium mixture contains 5.60 mol NH_3.

Calculate K_c, including units, at this temperature.
Give your answer to **three** significant figures.

K_c = ... units .... **[6]**

(c) The chemist repeats the experiment several times. In each experiment, the chemist makes one change.

(i) The chemist heats the mixture to a higher temperature at constant pressure.

Explain whether the value of K_c would be greater, smaller or the same.

....

....

.... **[1]**

(ii) The chemist increases the pressure of the mixture at constant temperature.

Explain whether the value of K_c would be greater, smaller or the same.

....

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.... **[1]**

[Total: 9]

7 Redox reactions are used in electrochemical cells and in analysis.

(a) **Table 7.1** shows two redox systems, and their standard electrode potentials, $E^{\ominus}$.

	Redox system	$E^{\ominus}$ **/ V**
1	$Cr^{3+}(aq) + 3e^{-} \rightleftharpoons Cr(s)$	–0.74
2	$Fe^{3+}(aq) + e^{-} \rightleftharpoons Fe^{2+}(aq)$	+0.77

Table 7.1

(i) A student sets up a standard cell in the laboratory based on redox systems **1** and **2**.

Draw a labelled diagram to show how the student could set up this cell to measure its standard cell potential.

State the conditions needed to measure this standard cell potential.

conditions: ....

....

.... **[4]**

(ii) Write down the overall cell reaction.

.... **[1]**

(iii) Write down the standard cell potential of this cell and state the sign of the chromium electrode.

standard cell potential = ... V

sign of chromium electrode = ... **[1]**

(b) The student makes the following change to their standard cell set up in **(a)**.

The student adds solid $CrCl_3$ to the Cr^{3+}(aq) / Cr(s) half-cell. The student stirs the solution to dissolve the $CrCl_3$.
The student finds that the cell potential has **decreased**.

Explain this observation, in terms of equilibrium and electrode potentials.

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.... **[3]**

(c) A new type of fuel cell has been developed based on HCOOH and O_2.

The equation for the overall cell reaction is shown below.

$$2HCOOH(l) + O_2(g) \rightarrow 2H_2O(l) + 2CO_2(g)$$

The half-equation at the oxygen electrode of this fuel cell is shown below.

$$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$$

(i) Deduce the half-equation at the other electrode of this fuel cell.

.... **[1]**

(ii) Suggest **one** advantage of this fuel cell over a hydrogen fuel cell.

....

.... **[1]**

(d) Redox reactions can be used in analysis.

Food additives containing sulfite ions, SO_3^{2-}, are often used as preservatives.

A student analyses a sample of hydrated sodium sulfite to find the formula of the hydrated salt.

The student titrates a solution of hydrated sodium sulfite with a standard solution of aqueous potassium manganate(VII), $KMnO_4$, under acidic conditions.

The method is outlined below.

- The student dissolves 2.400 g of hydrated sodium sulfite in water and makes the solution up to 250.0 cm^3.
- The student titrates 25.00 cm^3 volumes of this solution with 0.01500 mol dm^{-3} $KMnO_4$ under acidic conditions.

The mean titre is 25.40 cm^3.

In the titration, 2 mol of MnO_4^- reacts with 5 mol of SO_3^{2-}.

(i) Determine the formula of the hydrated sodium sulfite, showing clearly its water of crystallisation as a whole number.

formula = ... **[6]**

(ii) In the titration, a redox reaction takes place between MnO_4^-, SO_3^{2-} and H^+ ions:

- MnO_4^- ions are reduced to manganese(II) ions,
- SO_3^{2-} ions are oxidised to sulfate(VI) ions.

Construct the overall equation for the redox reaction and the half-equations that take place in the titration.

Overall equation:

....

Half-equations:

[3]

[Total: 20]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).