Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2014

Chemistry CHEM2

Unit 2 Chemistry in Action

Tuesday 3 June 2014 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use scientific terminology accurately.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

Section A

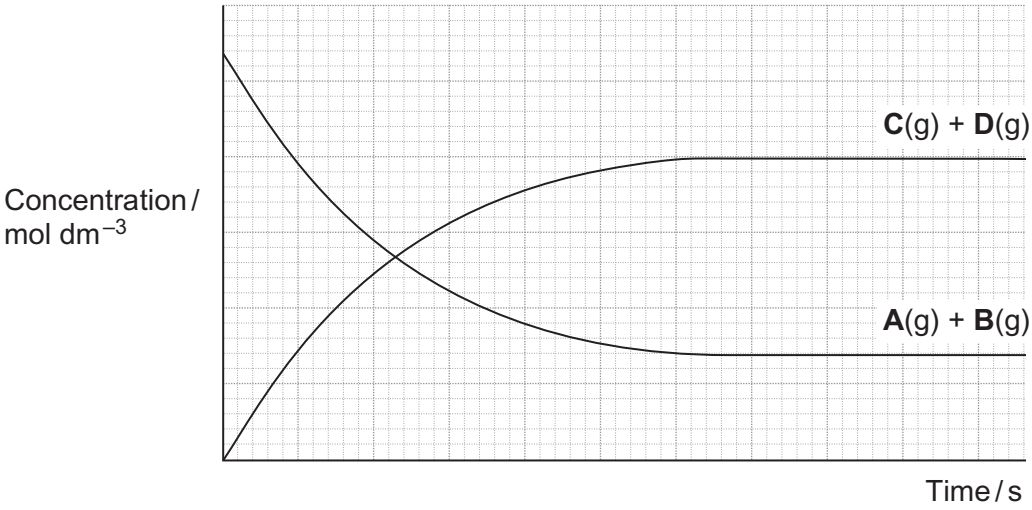
Answer **all** questions in the spaces provided.

1 A dynamic equilibrium is established when gas **A** is mixed with gas **B** at a given temperature.

$$\mathbf{A}(g) + \mathbf{B}(g) \rightleftharpoons \mathbf{C}(g) + \mathbf{D}(g)$$

Figure 1 shows how the concentrations of reactants and products change with time.

Figure 1



1 (a) (i) On the appropriate axis of **Figure 1**, place an **X** to show the time when equilibrium is first established.

[1 mark]

1 (a) (ii) State how the rate of the forward reaction and the rate of the reverse reaction are related to each other at equilibrium.

[1 mark]

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1 (b) Give the meaning of the term **dynamic** in the context of a dynamic equilibrium.

[1 mark]

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.....

1 (c) The total pressure on the system is increased at constant temperature.

1 (c) (i) State and explain the effect, if any, of this change on the position of this equilibrium.

[2 marks]

Effect .....

Explanation .....

.....

.....

.....

1 (c) (ii) State and explain the effect, if any, of this change on the time taken to reach this equilibrium.

[3 marks]

Effect .....

Explanation .....

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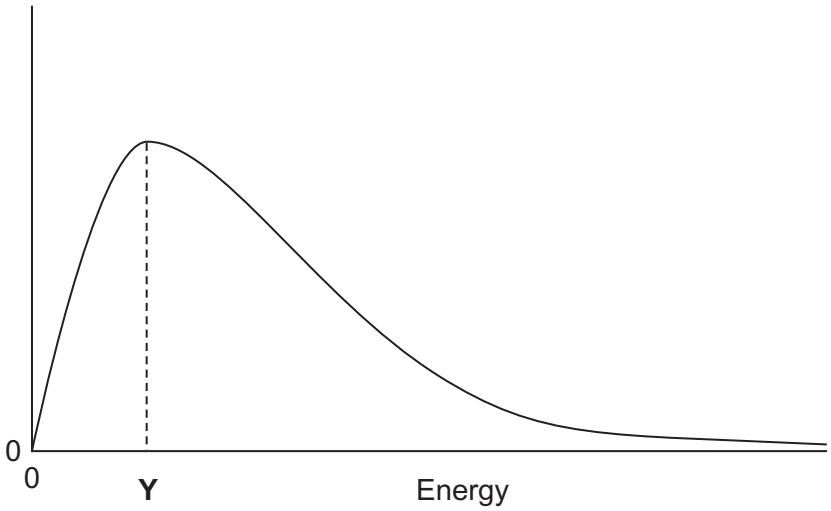
8

2 **Figure 2** shows the Maxwell–Boltzmann distribution of molecular energies in a sample of gas at temperature *T*.

Figure 2



2 (a) One of the axes is labelled.
Label the other axis.

[1 mark]

2 (b) State why the curve starts at the origin.

[1 mark]

.....

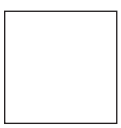
.....

.....

2 (c) Which of the following, **A**, **B** or **C**, describes what the value of **Y** represents in **Figure 2**?
Write the correct letter, **A**, **B** or **C**, in the box.

[1 mark]

A The energy needed for a successful collision
B The minimum energy needed for a reaction to occur
C The most probable energy



2 (d) On **Figure 2**, draw a distribution of molecular energies in this sample of gas at a **higher** temperature.

[2 marks]

2 (e) The pressure of the original sample of gas is doubled at temperature *T*.

State the effect, if any, of this change on the value of **Y**.

[1 mark]

.....

.....

6

Turn over for the next question

3 Antimony is a solid element that is used in industry. The method used for the extraction of antimony depends on the grade of the ore.

3 (a) Antimony can be extracted by reacting scrap iron with low-grade ores that contain antimony sulfide (Sb_2S_3).

3 (a) (i) Write an equation for the reaction of iron with antimony sulfide to form antimony and iron(II) sulfide.

[1 mark]

.....

3 (a) (ii) Write a half-equation to show what happens to the iron atoms in this reaction.

[1 mark]

.....

3 (b) In the first stage of the extraction of antimony from a high-grade ore, antimony sulfide is roasted in air to convert it into antimony(III) oxide (Sb_2O_3) and sulfur dioxide.

3 (b) (i) Write an equation for this reaction.

[1 mark]

.....

3 (b) (ii) Identify **one** substance that is manufactured directly from the sulfur dioxide formed in this reaction.

[1 mark]

.....

3 (c) In the second stage of the extraction of antimony from a high-grade ore, antimony(III) oxide is reacted with carbon monoxide at high temperature.

3 (c) (i) Use the standard enthalpies of formation in **Table 1** and the equation given below **Table 1** to calculate a value for the standard enthalpy change for this reaction.

Table 1

	$Sb_2O_3(s)$	CO(g)	Sb(l)	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−705	−111	+20	−394

$$Sb_2O_3(s) + 3CO(g) \longrightarrow 2Sb(l) + 3CO_2(g)$$

[3 marks]

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3 (c) (ii) Suggest why the value for the standard enthalpy of formation of liquid antimony, given in **Table 1**, is **not** zero.

[1 mark]

.....

.....

3 (c) (iii) State the type of reaction that antimony(III) oxide has undergone in this reaction.

[1 mark]

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3 (d) Deduce **one** reason why the method of extraction of antimony from a low-grade ore, described in part **3 (a)**, is a low-cost process. Do **not** include the cost of the ore.

[1 mark]

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10

4 There are many uses for Group 2 metals and their compounds.

4 (a) State a medical use of barium sulfate.
State why this use of barium sulfate is safe, given that solutions containing barium ions are poisonous.

[2 marks]

Use .....

Why this use is safe .....

.....

.....

4 (b) Magnesium hydroxide is used in antacid preparations to neutralise excess stomach acid.

Write an equation for the reaction of magnesium hydroxide with hydrochloric acid.

[1 mark]

.....

4 (c) Solutions of barium hydroxide are used in the titration of weak acids.

State why magnesium hydroxide solution could **not** be used for this purpose.

[1 mark]

.....

.....

4 (d) Magnesium metal is used to make titanium from titanium(IV) chloride.

Write an equation for this reaction of magnesium with titanium(IV) chloride.

[1 mark]

.....

4 (e) Magnesium burns with a bright white light and is used in flares and fireworks.

Use your knowledge of the reactions of Group 2 metals with water to explain why water should **not** be used to put out a fire in which magnesium metal is burning.

[2 marks]

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[Extra space] .....

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7

Turn over for the next question

5 Trifluoromethane (CHF_3) can be used to make the refrigerant chlorotrifluoromethane ($CClF_3$).

5 (a) Chlorotrifluoromethane is formed when trifluoromethane reacts with chlorine.

$$CHF_3 + Cl_2 \longrightarrow CClF_3 + HCl$$

The reaction is a free-radical substitution reaction similar to the reaction of methane with chlorine.

5 (a) (i) Write an equation for each of the following steps in the mechanism for the reaction of CHF_3 with Cl_2

[4 marks]

Initiation step

.....

First propagation step

.....

Second propagation step

.....

Termination step to form hexafluoroethane

.....

5 (a) (ii) Give **one** essential condition for this reaction.

[1 mark]

.....

5 (b) In some refrigeration systems, CHF_3 has replaced $CClF_3$ because of concerns about ozone depletion.

5 (b) (i) Identify the species formed from $CClF_3$ that is responsible for the catalytic decomposition of ozone in the upper atmosphere.

[1 mark]

.....

5 (b) (ii) Write an overall equation to represent the decomposition of ozone into oxygen.

[1 mark]

.....

7

Turn over for the next question

There are no questions printed on this page

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6 This question is about Group 7 chemistry.

6 (a) Sea water is a major source of iodine.
The iodine extracted from sea water is impure. It is purified in a two-stage process.

Stage **1** $I_2 + 2H_2O + SO_2 \longrightarrow 2HI + H_2SO_4$

Stage **2** $2HI + Cl_2 \longrightarrow I_2 + 2HCl$

6 (a) (i) State the initial oxidation state and the final oxidation state of sulfur in Stage **1**.
[2 marks]

Oxidation state of S in SO_2 .....

Oxidation state of S in H_2SO_4 .....

6 (a) (ii) State, in terms of electrons, what has happened to chlorine in Stage **2**.
[1 mark]

.....

.....

6 (b) When concentrated sulfuric acid is added to potassium iodide, iodine is formed in the following redox equations.

$$.....KI + ...H_2SO_4 \longrightarrow .....KHSO_4 + ...I_2 + S + ...H_2O$$

$$8KI + 9H_2SO_4 \longrightarrow 8KHSO_4 + 4I_2 + H_2S + 4H_2O$$

6 (b) (i) Balance the equation for the reaction that forms sulfur.
[1 mark]

6 (b) (ii) Deduce the half-equation for the formation of iodine from iodide ions.
[1 mark]

.....

6 (b) (iii) Deduce the half-equation for the formation of hydrogen sulfide from concentrated sulfuric acid.
[1 mark]

.....

Question 6 continues on the next page

6 (c) A yellow precipitate is formed when silver nitrate solution, acidified with dilute nitric acid, is added to an aqueous solution containing iodide ions.

6 (c) (i) Write the **simplest ionic** equation for the formation of the yellow precipitate.

[1 mark]

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6 (c) (ii) State what is observed when concentrated ammonia solution is added to this yellow precipitate.

[1 mark]

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6 (c) (iii) State why the silver nitrate solution is acidified when testing for iodide ions.

[1 mark]

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6 (c) (iv) Explain why dilute hydrochloric acid is **not** used to acidify the silver nitrate solution in this test for iodide ions.

[1 mark]

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6 (d) Chlorine is toxic to humans. This toxicity does not prevent the large-scale use of chlorine in water treatment.

6 (d) (i) Give **one** reason why water is treated with chlorine.

[1 mark]

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6 (d) (ii) Explain why the toxicity of chlorine does **not** prevent this use.

[1 mark]

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6 (d) (iii) Write an equation for the reaction of chlorine with cold water.

[1 mark]

.....

6 (e) Give the formulas of the **two** different chlorine-containing compounds that are formed when chlorine reacts with cold, dilute, aqueous sodium hydroxide.

[1 mark]

Formula 1 .....

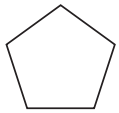
Formula 2 .....

14

Turn over for the next question

7 **Table 2** gives the names and structures of some structural isomers with the molecular formula C_5H_{10}

Table 2

	Name of isomer	Structure
Isomer **1**	pent-2-ene	$CH_3CH=CHCH_2CH_3$
Isomer **2**	cyclopentane	
Isomer **3**	3-methylbut-1-ene	$(CH_3)_2CHCH=CH_2$
Isomer **4**	2-methylbut-2-ene	$(CH_3)_2C=CHCH_3$
Isomer **5**	2-methylbut-1-ene	$H_2C=C(CH_3)CH_2CH_3$

7 (a) Isomer **1** exists as E and Z stereoisomers.

7 (a) (i) State the meaning of the term **stereoisomers.**

[2 marks]

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7 (a) (ii) Draw the structure of the E stereoisomer of Isomer **1**.

[1 mark]

7 (b) A chemical test can be used to distinguish between separate samples of Isomer **1** and Isomer **2**.

Identify a suitable reagent for the test.
State what you would observe with Isomer **1** and with Isomer **2**.

[3 marks]

Reagent.....

Observation with Isomer **1**.....

.....

Observation with Isomer **2**.....

.....

7 (c) Use **Table A** on the Data Sheet when answering this question.
Isomer **3** and Isomer **4** have similar structures.

7 (c) (i) State the infrared absorption range that shows that Isomer **3** and Isomer **4** contain the same functional group.

[1 mark]

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7 (c) (ii) State **one** way that the infrared spectrum of Isomer **3** is different from the infrared spectrum of Isomer **4**.

[1 mark]

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Question 7 continues on the next page

7 (d) Two alcohols are formed by the hydration of Isomer **4**.

Draw the **displayed formula** for the alcohol formed that is oxidised readily by acidified potassium dichromate(VI).

[1 mark]

7 (e) Isomer **4** reacts with hydrogen bromide to give two structurally isomeric bromoalkanes.

7 (e) (i) Name and outline a mechanism for the reaction of Isomer **4** with hydrogen bromide to give 2-bromo-2-methylbutane as the major product.

[5 marks]

$$(CH_3)_2C{=}CHCH_3 \;+\; HBr \longrightarrow (CH_3)_2CBrCH_2CH_3$$

Name of mechanism.....

Mechanism

7 (e) (ii) The minor product in this reaction mixture is 2-bromo-3-methylbutane.

Explain why this bromoalkane is formed as a minor product.

[2 marks]

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7 (f) Name and outline a mechanism for the following reaction to form Isomer **5**.
State the role of the hydroxide ion in this reaction.

[5 marks]

$(CH_3)_2CBrCH_2CH_3 + KOH \longrightarrow H_2C=C(CH_3)CH_2CH_3 + KBr + H_2O$

Name of mechanism .....

Mechanism

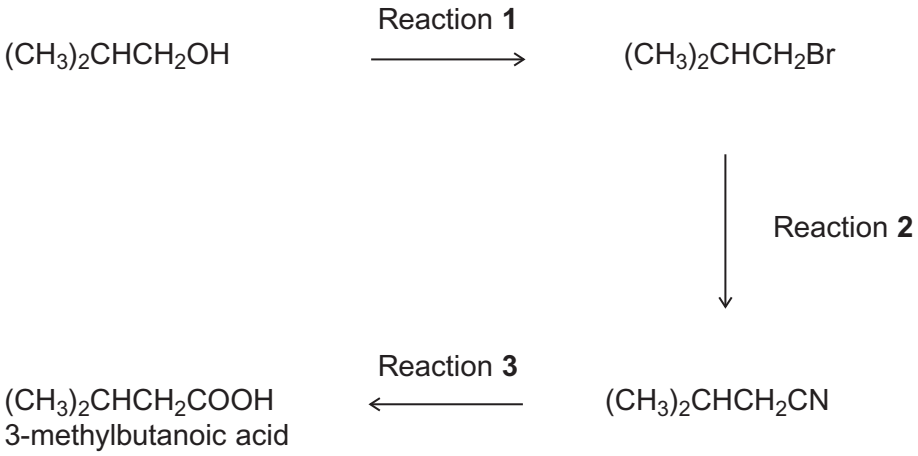
Role of hydroxide ion .....

21

Section B

Answer **all** questions in the spaces provided.

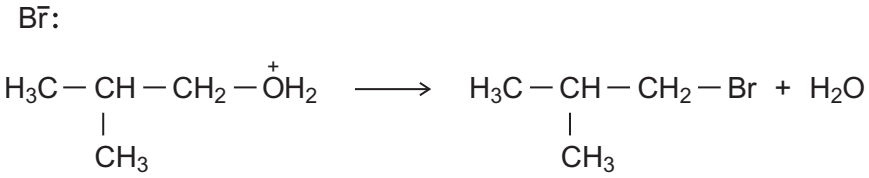
8 The carboxylic acid 3-methylbutanoic acid is used to make esters for perfumes. The following scheme shows some of the reactions in the manufacture of this carboxylic acid.



8 (a) One of the steps in the mechanism for Reaction **1** involves the replacement of the functional group by bromine.

8 (a) (i) Use your knowledge of organic reaction mechanisms to complete the mechanism for this step by drawing **two** curly arrows on the following equation.

[2 marks]



8 (a) (ii) Deduce the name of the mechanism in Question **8 (a) (i)**.

Give the IUPAC name of $(CH_3)_2CHCH_2Br$

[2 marks]

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8 (b) Reaction **3** is an acid-catalysed reaction in which water is used to break chemical bonds when the CN functional group is converted into the COOH functional group. Infrared spectroscopy can be used to distinguish between the compounds in this reaction.

Deduce the name of the type of reaction that occurs in Reaction **3**.

Identify **one** bond in $(CH_3)_2CHCH_2CN$ and a **different** bond in $(CH_3)_2CHCH_2COOH$ that can be used with infrared spectroscopy to distinguish between each compound. For each of these bonds, give the range of wavenumbers at which the bond absorbs. Use **Table A** on the Data Sheet when answering this question.

[3 marks]

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Question 8 continues on the next page

8 (c) When 3-methylbutanoic acid reacts with ethanol in the presence of an acid catalyst, an equilibrium is established. The organic product is a pleasant-smelling ester.

$$(CH_3)_2CHCH_2COOH + CH_3CH_2OH \rightleftharpoons \underset{\text{an ester}}{(CH_3)_2CHCH_2COOCH_2CH_3} + H_2O$$

The carboxylic acid is very expensive and ethanol is inexpensive. In the manufacture of this ester, the mole ratio of carboxylic acid to ethanol used is 1 to 10 rather than 1 to 1.

8 (c) (i) Use Le Chatelier's principle to explain why a 1 to 10 mole ratio is used. In your explanation, you should **not** refer to cost.

[3 marks]

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[Extra space] .....

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8 (c) (ii) Explain how a catalyst increases the rate of a reaction.

[2 marks]

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[Extra space] .....

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12

9 Ethanol is an important fuel.

9 (a) A dilute aqueous solution of ethanol can be produced by the fermentation of an aqueous solution of glucose.
It is claimed that the ethanol obtained from this solution is a carbon-neutral biofuel.

Write an equation for this fermentation reaction.

Give **two** other essential conditions for this reaction to produce a good yield of ethanol.

Name a process used to produce a much more concentrated solution of ethanol from a dilute aqueous solution.

State the meaning of the term **carbon-neutral** in the context of this biofuel.

[5 marks]

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[Extra space] .....

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Question 9 continues on the next page

9 (b) A student carried out a laboratory experiment to determine the enthalpy change when a sample of ethanol was burned. The heat produced was used to warm some water in a copper calorimeter. The student found that the temperature of 75.0 g of water increased by 5.50 ºC when 2.40×10^{-3} mol of pure ethanol was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of ethanol is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

Deduce **two** reasons why the student's value for the standard enthalpy of combustion of ethanol is different from a Data Book value of –1279 kJ mol^{-1}.

[5 marks]

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[Extra space].....

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9 (c) Mean bond enthalpies can be used to calculate enthalpies of reaction.

9 (c) (i) Give the meaning of the term **mean bond enthalpy**.

[2 marks]

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9 (c) (ii) Consider the mean bond enthalpy data in **Table 3**.

Table 3

	C—H	**C—C**	**C—O**	**O=O**	**C=O**	**O—H**
Mean bond enthalpy / kJ mol^{-1}	412	348	360	to be calculated	805	463

Use the data in **Table 3** and the equation shown to calculate a value for the bond enthalpy for the O=O double bond in an oxygen molecule.

[3 marks]

$$CH_3CH_2OH(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g) \quad \Delta H = -1279 \text{ kJ mol}^{-1}$$

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END OF QUESTIONS

15

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