Rate of Reaction

Question Paper

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Rate of Reaction- Gases and kinetics
Booklet	Question Paper

Time Allowed: **59 minutes**

Score: **/49**

Percentage: **/100**

Grade Boundaries:

1 A goal of chemists is to create a viable process that, like photosynthesis, will convert carbon dioxide into fuel.

(a) A recent development (reported in *Science*, 2010) is to concentrate sunlight onto cerium(IV) oxide, in contact with carbon dioxide and water, to make carbon monoxide, hydrogen and oxygen.

The standard enthalpy changes of formation are given.

substance	$\Delta_f H^\ominus$ (298 K) / kJ mol^{-1}
$CO_2(g)$	−393.5
$H_2O(l)$	−285.8
CO(g)	−110.5

(i) Calculate the standard enthalpy change of reaction at 298 K for the reaction between CO_2 and H_2O.

Give your answer to one decimal place and include a sign in your answer.

$$CO_2 + H_2O \rightarrow CO + H_2 + O_2$$

$\Delta_r H^\ominus$ (298 K) = ... kJ mol^{-1} [2]

(ii) Suggest the role of cerium(IV) oxide in this reaction.

..... [1]

(b) A mixture of carbon monoxide and hydrogen is known as synthesis gas. Synthesis gas can be converted to methanol.

$CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$ $\Delta_r H^{\ominus}$ (298 K) = −128.6 kJ mol^{-1}

(i) Define the term *standard enthalpy change of combustion*.

.....

.....

.....

..... [3]

(ii) Use the value of the enthalpy change given and data from **(a)** to find the standard enthalpy change of combustion of methanol.

Give your answer to one decimal place and include a sign in your answer.

$\Delta_c H^{\ominus}$ (298 K) = ... kJ mol^{-1} [2]

(iii) Methanol is a useful fuel; however, synthesis gas is also a fuel in its own right.

Suggest one advantage in converting synthesis gas to methanol.

.....

..... [1]

(c) A recent proposal (reported in *Energy & Environmental Science*, 2011) is to obtain the carbon dioxide for the process in part **(a)** by concentrating solar energy on calcium carbonate in order to make it decompose.

(i) Write the equation for this reaction of calcium carbonate.

..... [1]

(ii) State and explain whether more or less solar energy would be required to decompose the same number of moles of magnesium carbonate.

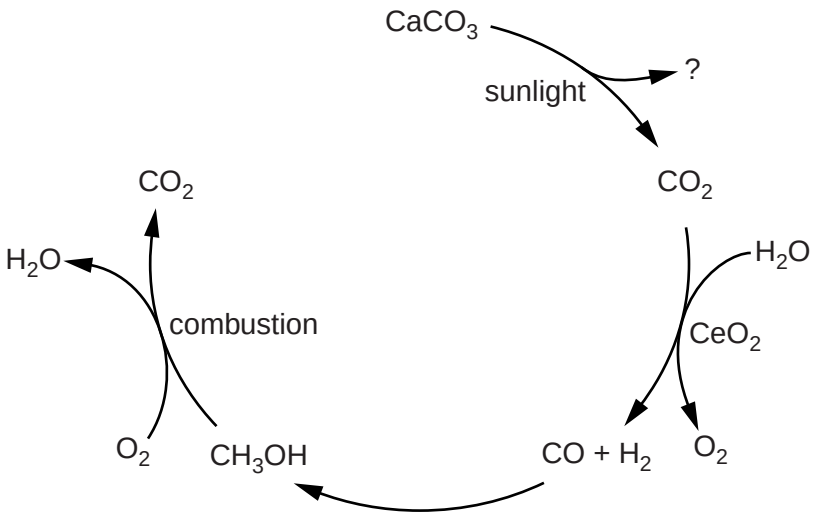
.....

.....

.....

..... [2]

(iii) The flow diagram summarises all the reactions in this question.



Suggest what extra step would complete the cycle and lower the carbon footprint of the overall process.

.....

.....

..... [1]

[Total: 13]

2 **(a)** Group 2 carbonates decompose when heated.

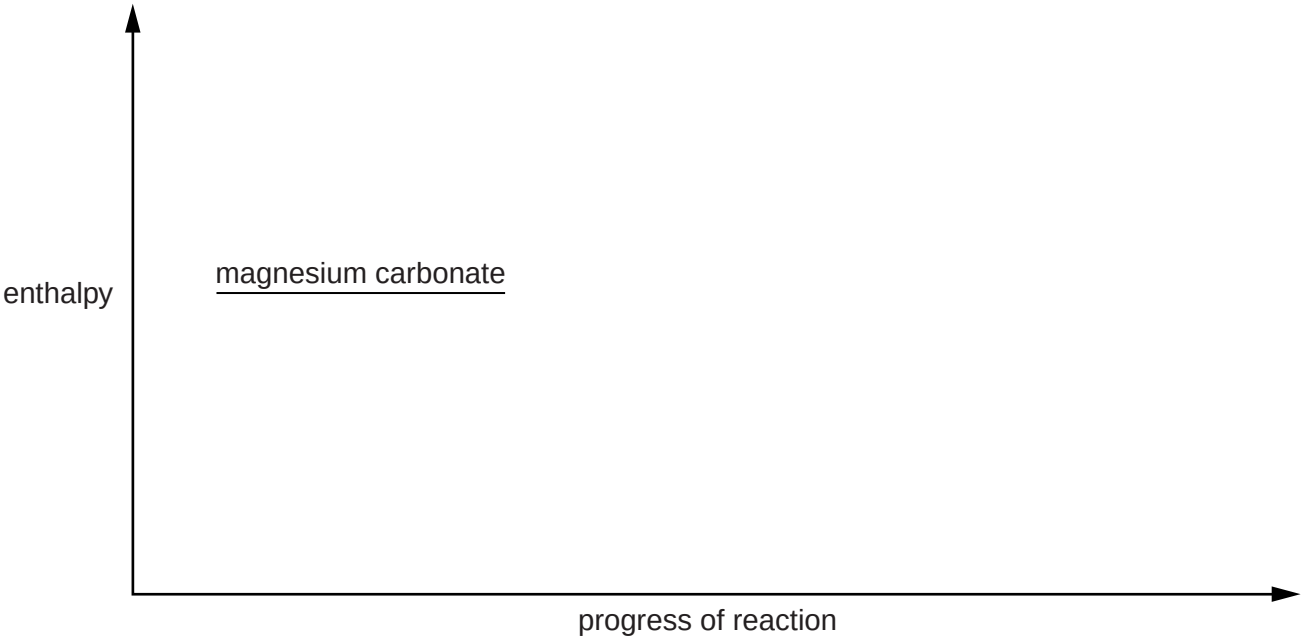
(i) Write the equation for the thermal decomposition of magnesium carbonate.

..... [1]

(ii) Complete the reaction profile diagram for the thermal decomposition of magnesium carbonate.

On the diagram, label

- the enthalpy change of reaction, $\Delta_r H$,
- the activation energy, E_a.



[3]

(b) There is a trend in the decomposition temperature of Group 2 carbonates as the group is descended.

State and explain this trend.

trend .....

explanation .....

.....

.....

.....

.....

[4]

(c) The cement-making process involves the thermal decomposition of calcium carbonate. This process is the second largest emitter of greenhouse gases globally after power generation.

There is presently much interest in serpentine, $Mg_3Si_2O_5(OH)_x$, as a "green" cement which chemically absorbs carbon dioxide.

(i) Deduce the value of x in $Mg_3Si_2O_5(OH)_x$.

x = ... [1]

(ii) Serpentine cement reacts with carbon dioxide to form water, silicon(IV) oxide and one other product.

Suggest the identity of the other product.

..... [1]

(iii) Magnesium oxide can be considered to be an intermediate in the process in **(c)(ii)**.

What type of chemical reaction takes place between magnesium oxide and carbon dioxide?

..... [1]

(d) Dolomite is a carbonate-containing mineral with formula $CaZ(CO_3)_2$ where Z is a metal ion.

(i) Use the formula of dolomite to determine the charge on the metal ion Z.

..... [1]

(ii) Dolomite is insoluble in water but dissolves in acid. The ionic equation for the reaction between hydrogen ions and carbonate ions is shown.

$$2H^+(aq) + CO_3^{2-}(aq) \longrightarrow CO_2(g) + H_2O(l)$$

A 5.00 g sample of dolomite is dissolved in 30.0 cm^3 of 5.00 mol dm^{-3} hydrochloric acid, an excess.

The resulting solution is made up to 100 cm^3 in a volumetric flask, using distilled water. 10.0 cm^3 of this solution is titrated against a 0.100 mol dm^{-3} solution of sodium hydroxide. An average titre of 41.60 cm^3 is obtained.

Calculate the amount, in mol, of excess hydrochloric acid in the 100 cm^3 volumetric flask. Use an appropriate number of significant figures in your answer.

amount = ... mol [3]

(iii) Calculate the amount, in mol, of hydrochloric acid that reacts with the 5.00 g sample of dolomite.

amount = ... mol [2]

(iv) Calculate the mass of carbonate ions in the 5.00 g sample of dolomite.

mass = ... g [2]

(v) Determine the molar mass of the metal ion *Z*.

molar mass = ... g mol^{-1} [3]

[Total: 22]

3. Table 1.1 gives some data on four fuel sources: methanol, ethanol, hydrogen and octane. Octane can serve as a rough approximation of petrol.

Table 1.1

name	formula	molar mass / g mol^{-1}	density / g cm^{-3}	$\Delta_c H^{\ominus}$ (298 K) / kJ mol^{-1}	$\Delta_f H^{\ominus}$ (298 K) / kJ mol^{-1}
methanol	CH_3OH	32	0.793[a]	–726.0	–239.1
ethanol	C_2H_5OH		0.789[a]	–1367.3	–277.1
liquid hydrogen	H_2	2	0.0711[b]		
octane	C_8H_{18}		0.703[a]		–250.0

[a] At 298 K and 1 bar pressure.
[b] At 20 K and 1 bar pressure.

(a) Insert the missing molar mass values in the table. [1]

(b) Calculate the density of **gaseous** hydrogen at 298 K and 1 bar pressure.
Assume 1 mol of any gas occupies 24 dm^3 at 298 K and 1 bar pressure. Give your answer in g cm^{-3}.

..... g cm^{-3} [1]

(c) What is the value of the standard enthalpy of formation of hydrogen **gas**, H_2?

..... [1]

(d) Use the information in Table 1.2 to give the value of the standard enthalpy of combustion of hydrogen.

Table 1.2

name	$\Delta_f H^{\ominus}$ (298 K) / kJ mol^{-1}
water	–285.8
carbon dioxide	–393.5

..... [1]

(e) Write down the chemical equation that represents the standard enthalpy of combustion of octane. Include state symbols.

..... [2]

(f) Use the enthalpy of formation data in Table 1.1 and Table 1.2 to calculate the standard enthalpy of combustion of octane.

.....[3]

(g) An important property of a fuel, especially when the fuel has to be lifted (such as in aviation), is the energy released on combustion *per gram* of fuel.

Calculate the enthalpy change of combustion per gram of fuel at 1 bar pressure and 298 K for methanol and hydrogen gas.

(i) methanol

.....

(ii) hydrogen gas

.....[2]

(h) Another important characteristic of a fuel, especially when there is a fuel tank of limited size, is the energy released on combustion *per* cm^3 of fuel.

Calculate the enthalpy change of combustion per cm^3 of fuel for ethanol and octane.

(i) ethanol

.....

(ii) octane

.....[2]

(i) Explain why, given the data in the question, it is not strictly possible to make a fair comparison of the energy released per cm^3 of liquid hydrogen with the other fuels.

.....

.....[1]

[Total: 14]