Energy changes

Question Paper 1

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Energy changes- Physical Chemistry
Booklet	Question Paper 1

Time Allowed: **64 minutes**

Score: **/53**

Percentage: **/100**

Grade Boundaries:

1 **(a)** **(i)** What is meant by the term *bond energy*?

.....

.....

..... [3]

(ii) Use the bond energy data in the table to find the enthalpy change of reaction for the reaction between ethane and chlorine shown below.

$$C_2H_6(g) + 2Cl_2(g) \rightarrow C_2H_4Cl_2(g) + 2HCl(g)$$

bond	average bond energy / kJ mol^{-1}
C−C	347
C−H	413
Cl−Cl	243
C−Cl	346
H−Cl	432

[3]

(b) At low temperatures and pressures the alkali metals can exist as gaseous diatomic molecules. Recent research has investigated the mixing of gaseous diatomic molecules of different alkali metals (reported in *Science* 2010).

Spectroscopic techniques can be used to measure the bond energies of diatomic molecules. When measured in this way the values of bond energies are given in wavenumbers, which has the unit cm^{-1}.

Some values are shown in the table.

diatomic molecule	bond energy / cm^{-1}
K_2	4405
Rb_2	3966
KRb	4180

(i) Calculate the enthalpy change, in cm^{-1}, for the reaction between K_2 and Rb_2.

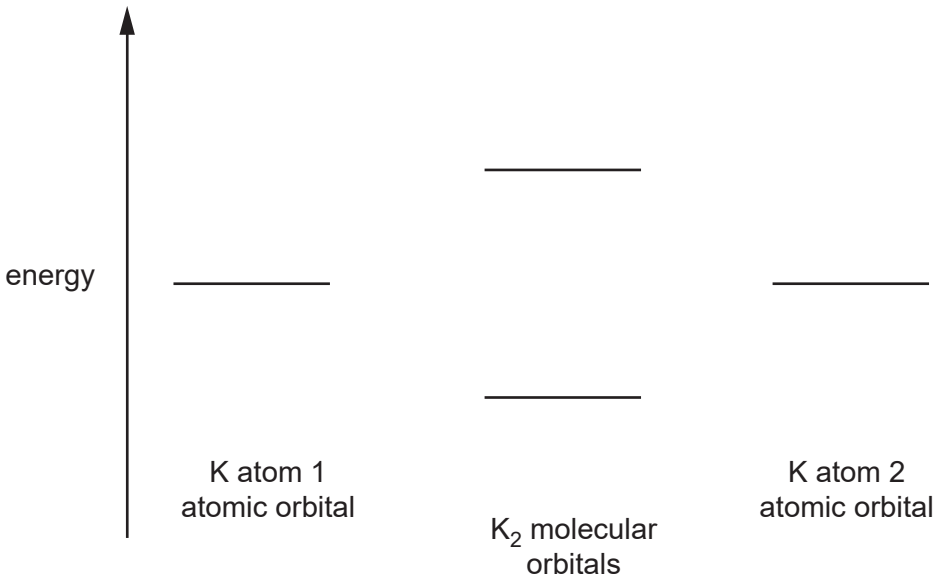
$$K_2(g) + Rb_2(g) \rightarrow 2KRb(g)$$

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

(ii) Complete the electron configuration of a potassium atom.

$1s^2$ ..... [1]

(iii) If only the outer shell electrons are considered, the molecular orbital diagram for an alkali metal diatomic molecule is much like that for hydrogen, H_2. Label all the orbitals in the molecular orbital diagram for K_2 and include the electrons.



[3]

(iv) Explain why potassium has a greater first ionisation energy than rubidium.

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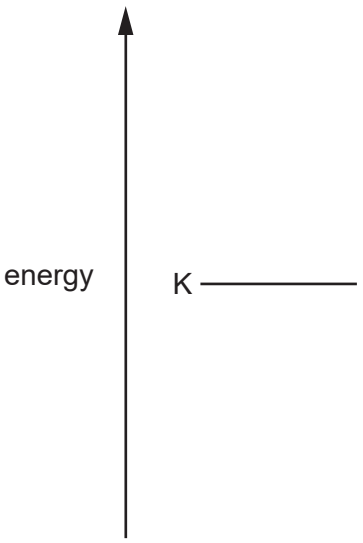
.....

..... [3]

(v) Complete the molecular orbital diagram for KRb, showing relevant atomic and molecular orbitals. Only include outer shell orbitals. Label all the orbitals in your diagram.



[2]

(vi) Wavenumbers, $\bar{\nu}$, are converted into energy, E, using the equation

$$E = hc\,\bar{\nu}$$

where h is Planck's constant and c is the speed of light.

Using your answer to **(b)(i)**, work out the enthalpy change in $kJ\,mol^{-1}$ for the reaction between K_2 and Rb_2.

..... $kJ\,mol^{-1}$ [2]

[Total: 18]

2. 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.

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

$\Delta_r H^{\ominus}$ (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.

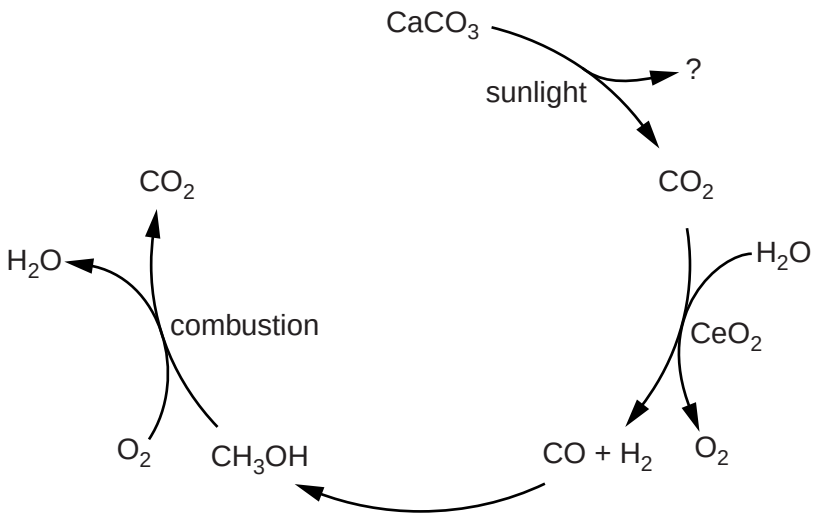
.....

.....

.....

..... [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.

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.....

..... [1]

[Total: 13]

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

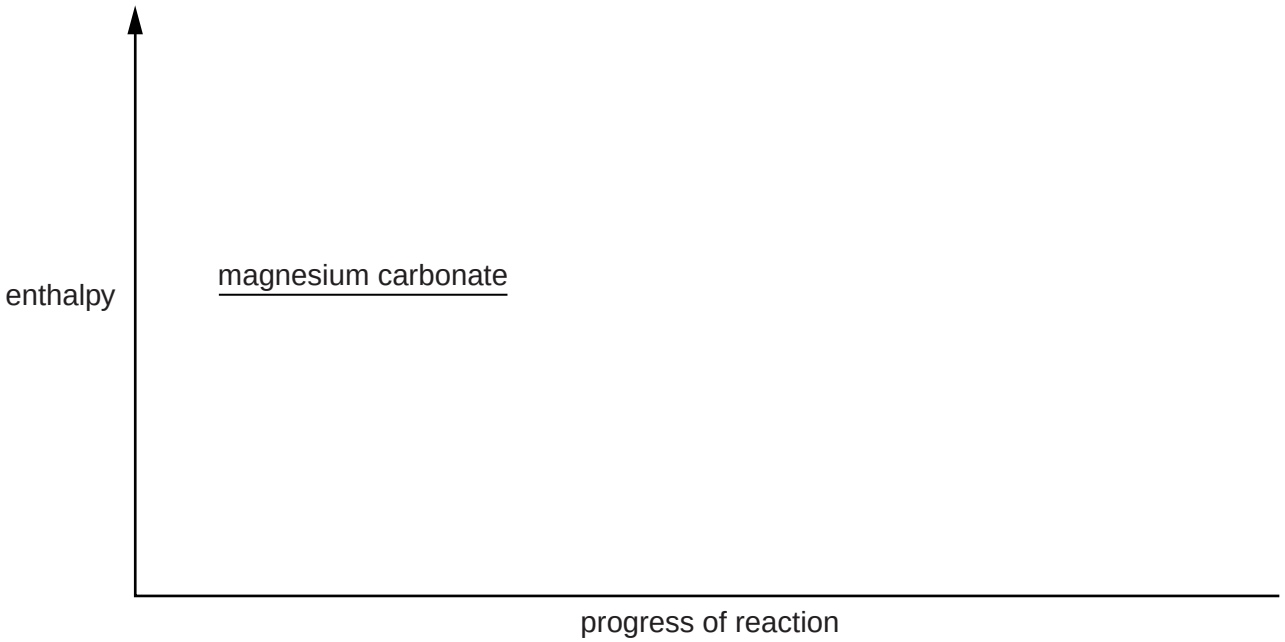
(i) Write the equation for the thermal decomposition of magnesium carbonate.

..... [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]