Additional Assessment Materials

Summer 2021

# Pearson Edexcel GCE in Chemistry 8CH0

## Resource Set 2 – Topic Group 4

Topics included:

Topic 8: Energetics I

Topic 9: Kinetics I and Topic 10: Equilibrium I

(Public release version)

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Additional Assessment Materials, Summer 2021

**General guidance to Additional Assessment Materials for use in 2021**

**Context**

- Additional Assessment Materials are being produced for GCSE, AS and A levels (with the exception of Art and Design).
- The Additional Assessment Materials presented in this booklet are an **optional** part of the range of evidence teachers may use when deciding on a candidate's grade.
- 2021 Additional Assessment Materials have been drawn from previous examination materials, namely past papers.
- Additional Assessment Materials have come from past papers both published (those materials available publicly) and unpublished (those currently under padlock to our centres) presented in a different format to allow teachers to adapt them for use with candidate.

**Purpose**

- The purpose of this resource to provide qualification-specific sets/groups of questions covering the knowledge, skills and understanding relevant to this Pearson qualification.
- This document should be used in conjunction with the mapping guidance which will map content and/or skills covered within each set of questions.
- These materials are only intended to support the summer 2021 series.

**4** Ethanol, $C_2H_5OH$, is a member of the homologous series of alcohols.

(a) Calculate the number of molecules in 55.2 kg of ethanol.

[Avogadro Constant = $6.02 \times 10^{23}$ $mol^{-1}$]

**(2)**

| number of molecules = moles x avogadros constant |
|---|

$$\text{moles} = \frac{55.2 \times 1000}{46} = 1200$$

$$n(\text{molecules}) = 1200 \times 6.02 \times 10^{23}$$

$$= 7.224 \times 10^{26} \text{ molecules}$$

(b) Write the equation to represent the standard enthalpy change of formation of ethanol. Include state symbols.

**(2)**

$$2C_{(s)} + 3H_{2(g)} + \frac{1}{2}O_{2\,(g)} \longrightarrow C_2H_5OH_{(l)}$$

(c) Ethanol burns completely in excess oxygen.

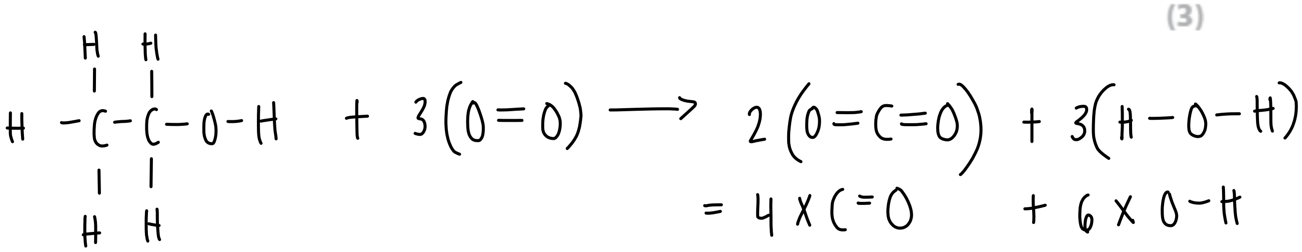
$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

(i) The table shows some mean bond enthalpy data.

| **Bond** | C—C | C—H | C—O | O—H | O═O | C═O |
|---|---|---|---|---|---|---|
| **Mean bond enthalpy / kJ mol$^{-1}$** | 347 | 413 | 358 | 464 | 498 | 805 |

Calculate the enthalpy change, in kJ mol$^{-1}$, for the complete combustion of 1 mol of ethanol.

**(3)**



= 4 × C=O + 6 × O–H

$\Delta H = \Sigma\Delta H(\text{bonds broken}) - \Sigma\Delta H(\text{bonds made})$

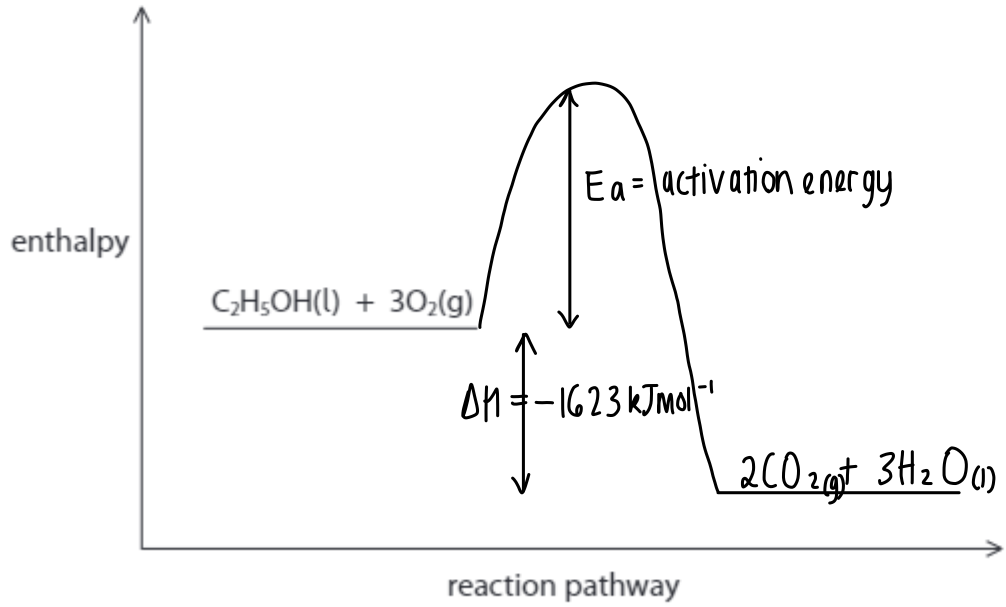
$= [(5 \times 413) + 358 + 464 + 3(498)] - [4(805) + 6(464)]$

$= 4381 - 6004$

$\Delta H = -1623 \text{ kJmol}^{-1}$

(ii) Complete the reaction profile diagram for the combustion of ethanol and fully label the diagram.

**(2)**




(iii) A data book value for the standard enthalpy change of combustion of ethanol is $-1367.3 \text{ kJ mol}^{-1}$.

Give the **main** reason why the value you calculated in (b)(i) is different from this data book value.

**(1)**

incomplete combustion

**(Total for Question 4 = 10 marks)**

**8** Compound **X** reacts slowly with water according to the following equation.

$$\mathbf{X}(s) + H_2O(l) \rightarrow \mathbf{Y}(aq) + Z^-(aq) + H^+(aq)$$

The reaction is catalysed by hydrogen ions and eventually goes to completion.

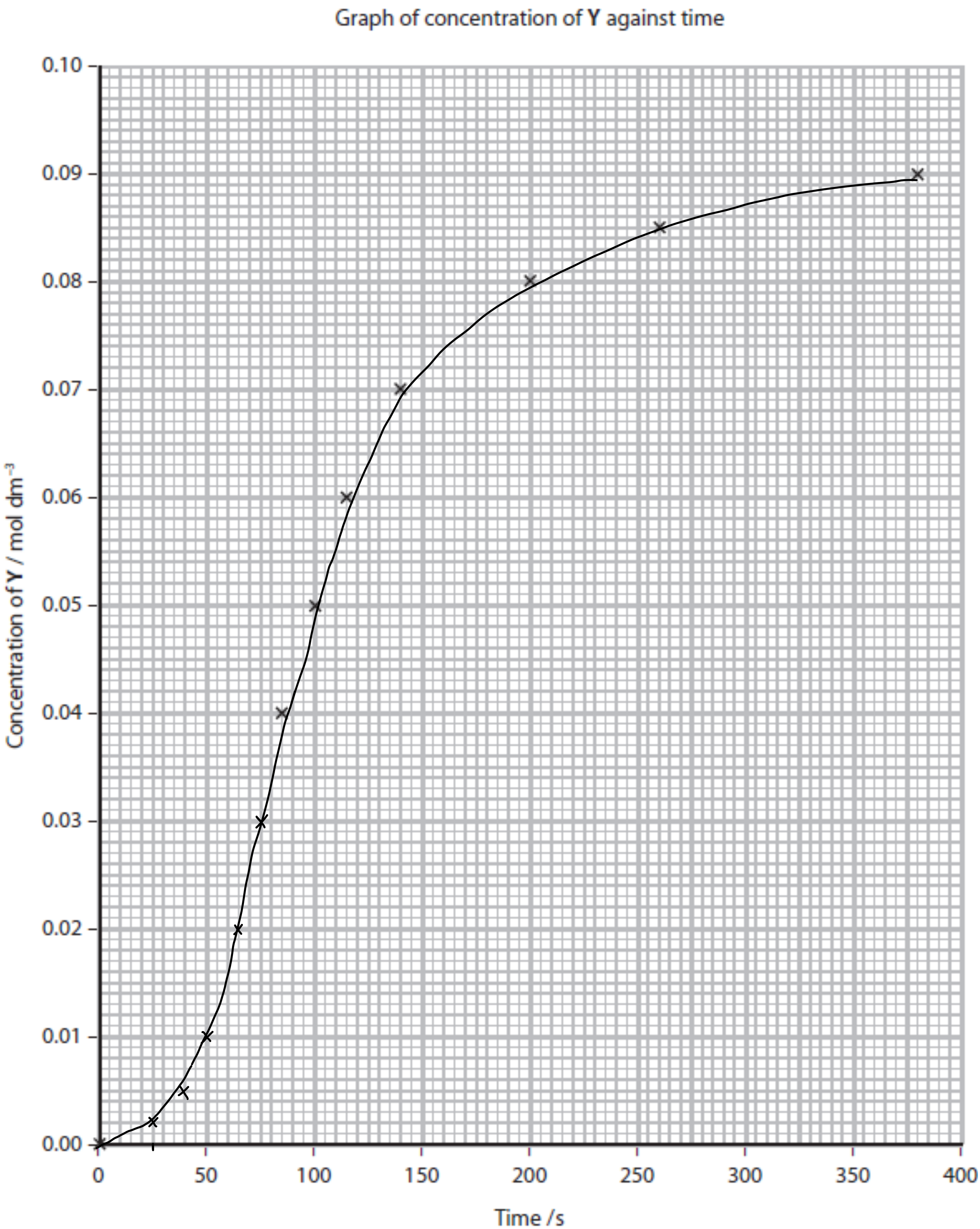
Compound **X** was added to water and the concentration of compound **Y** determined at various times at a constant temperature.

The results of the experiment are shown.

| Time / s | Concentration of **Y** / mol dm$^{-3}$ |
|---|---|
| 0 | 0.000 |
| 25 | 0.002 |
| 40 | 0.005 |
| 50 | 0.010 |
| 65 | 0.020 |
| 75 | 0.030 |
| 85 | 0.040 |
| 100 | 0.050 |
| 115 | 0.060 |
| 140 | 0.070 |
| 200 | 0.080 |
| 260 | 0.085 |
| 380 | 0.090 |

(a) (i) Complete the graph of concentration against time by adding the six missing points.
Draw a line to pass through **all** the points.

**(2)**


Graph of concentration of Y against time
Concentration of Y / mol dm⁻³
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
50
100
150
200
250
300
350
400
Time /s

(ii) Describe how you would find a numerical value for the initial rate of reaction and for the maximum rate of reaction in this experiment from the graph. No actual calculations are required.

(4)

to find the initial rate of reaction, draw a tangent to the curve at t=0 and then calculate the gradient of the tangent.

To find the maximum rate of reaction, divide the maximum [Y] formed by the total time of the reaction.

(b) For many reactions, the values of the initial rate and the maximum rate are the same.

Explain why the values of the two reaction rates obtained in this experiment are different from each other.

(2)

the rate of reaction is very slow at first because the $H^+$ ions (product) has not been formed yet, so the reaction does not start being catalysed until ~50s.

(c) Give a reason why the measurement of the initial rate of reaction is likely to be less accurate than the measurement of the maximum rate.

(1)

initial rate doesn't include the catalyst

**(Total for Question 8 = 9 marks)**

**4** Methanol is manufactured from a mixture of carbon monoxide and hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -90.8\,kJ\,mol^{-1}$$

(a) Give **two** characteristics of all reactions at equilibrium.

(2)

- forward and reverse reactions are occurring at the same rate
- the concentrations of the reactants and products remain constant

(b) (i) How does the equilibrium yield of methanol change if the temperature is increased at constant pressure or the pressure increased at constant temperature?

(1)

| | Equilibrium yield when temperature is increased | Equilibrium yield when pressure is increased |
|---|---|---|
| ☐ **A** | decrease | decrease |
| ☒ **B** | decrease | increase |
| ☐ **C** | increase | decrease |
| ☐ **D** | Increase | increase |

(ii) Explain your answer to (b)(i).

(2)

The forward reaction is exothermic so increasing the temperature would move the equilibrium to the left, in the endothermic direction, in order to decrease the temperature (according to Le Chatelier's Principle).

There are less moles on the right side of the equation (1 vs 3) so increasing the pressure moves the equilibrium to the side with less moles of gas to decrease the pressure.

(c) Explain why, in the industrial process involving this reaction, a catalyst is used.

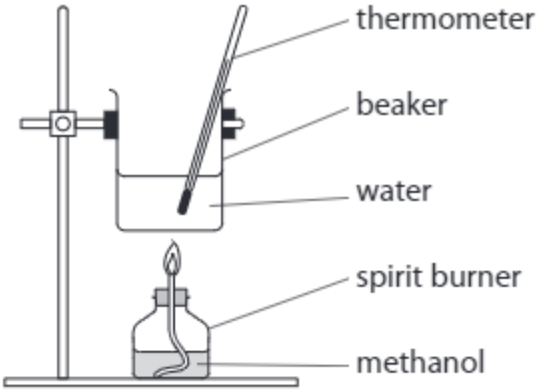
(2)

In order to obtain a high yield of methanol, a low temperature is needed. Decreasing the temperature decreases the rate of reaction as the molecules move slower and there are less frequent successful collisions, so a catalyst increases the rate of reaction.

**(Total for Question 4 = 7 marks)**

4 Methanol, $CH_3OH$, is a liquid fuel.

An experiment was carried out to determine the enthalpy change of combustion of liquid methanol.




$Mr(CH_3OH) = 32\ gmol^{-1}$

The energy obtained from burning 2.08 g of methanol was used to heat 75.0 g of water.

The temperature of the water rose from 25.0 °C to 91.0 °C.

[Specific heat capacity of water = 4.18 J g$^{-1}$ °C$^{-1}$]

(a) Use the data to calculate a value for the enthalpy change of combustion of one mole of methanol.

Give your answer to an appropriate number of significant figures and include a sign and units.

(4)

$q = mc\Delta T$

$q = 75 \times 4.18 \times 66$

$q = 20691\ J = 20.691\ kJ$

$\text{moles}\ (CH_3OH) = \frac{2.08}{32} = 0.065$

$\Delta H = \frac{20.691}{0.065}$

$= 318.3\ kJmol^{-1}$

$\Delta H = -318\ kJmol^{-1}$

($\Delta H$ is negative as it's an exothermic reaction)

(b) Methanol can be synthesised from methane and steam by a process that occurs in two steps.

Step **1** $CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H = +206\,kJ\,mol^{-1}$

Step **2** $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $\Delta H = -91\,kJ\,mol^{-1}$

(i) Explain the effects of increasing the pressure on the yield of the products and on the rate of the reaction in Step **1**.

(4)

Increasing the pressure decreases the yield of products because there are more moles of gas on the right side of the equation (4 moles on right vs 2 moles on left) so the equilibrium moves to the side with less moles of gas in order to decrease the pressure.

Increasing the pressure increases the rate of reaction as there are more molecules in a given volume so more frequent successful collisions.

These are both due to Le Chatelier's principle.

(ii) Step **2** is carried out at a compromise temperature of 500 K.

Explain why 500 K is considered to be a compromise for Step **2** by considering what would happen at higher and lower temperatures.

(3)

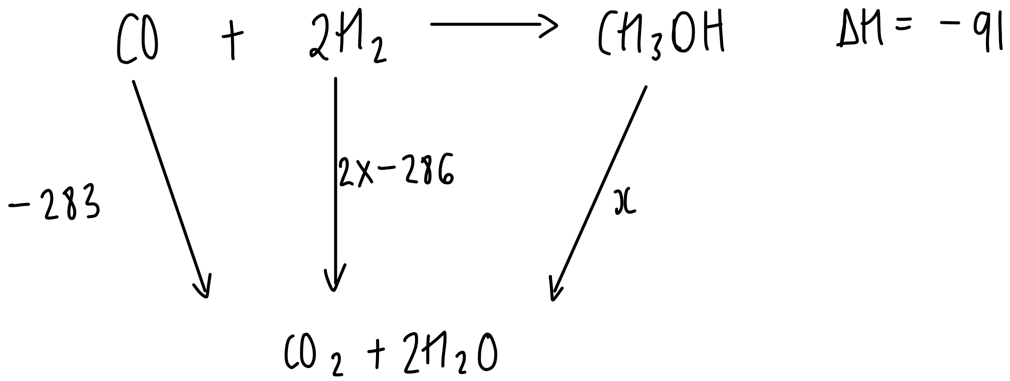
At a lower temperature, the yield of methanol would increase as the forward reaction is exothermic but the rate of reaction would be too slow. Increasing the temperature would increase the rate of reaction but decrease the yield of product,* so the compromise temperature maximises the yield whilst keeping the rate of reaction fast.

* due to Le Chatelier's Principle.

(c) Calculate a value for the standard enthalpy change of combustion of gaseous methanol using the enthalpy change for Step **2** and the standard enthalpy change of combustion of gaseous carbon monoxide and of hydrogen.

| Substance | Standard enthalpy change of combustion / kJ mol$^{-1}$ |
|---|---|
| CO | −283 |
| $H_2$ | −286 |

**(3)**




$$-283 + (2\times-286) - x = -91$$

$$\Rightarrow x = -764 \text{ kJmol}^{-1}$$

**(Total for Question 4 = 14 marks)**

**Total for Paper = 40 marks**