Additional Assessment Materials

Summer 2021

Pearson Edexcel GCE in Chemistry 9CH0

Resource Set 2 - Topic Group 2

Topics included:

Topic 8: Energetics I

Topic 9: Kinetics I

Topic 10: Equilibrium I

Topic 11: Equilibrium II

Topic 12: Acid-base Equilibria

Topic 13: Energetics II

Topic 16: Kinetics II

(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- Additional Assessment Materials have come from past papers both published (those materials available publicly) and unpublished (those currently under padlock to our centres) presented in a different format to allow teachers to adapt them for use with candidate.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.

3 Nitric acid reacts with sodium hydroxide solution in a neutralisation reaction.

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

In an experiment to determine the enthalpy change of neutralisation, the following results were obtained.

Volume of 1.00 mol dm^{-3} HNO_3 = 25.0 cm^3

Volume of 1.05 mol dm^{-3} NaOH = 25.0 cm^3

Temperature rise = 6.8 °C

(a) Give a reason why excess sodium hydroxide was used.

(1)

To ensure that all the nitric acid is used up in the reaction.

(b) Calculate the enthalpy change of neutralisation for the reaction between nitric acid and sodium hydroxide solution, using the results of the experiment.

Give your answer to an appropriate number of significant figures.

[Assume: density of the reaction mixture = 1.0 g cm^{-3}
specific heat capacity of the reaction mixture = 4.18 J g^{-1} °C^{-1}]

(4)

$d = \frac{m}{v}$ $\quad m = 50 \times 1$ $\quad 1 = \frac{m}{50}$ $\quad M = 1 \times 50 = 50g = 0.05kg$

$Q = mC\Delta T = 0.05 \times 4.18 \times 6.8 = 1.4212$ kJ

moles of HNO_3 $= \frac{c \times v}{1000} = \frac{1 \times 25}{1000} = 0.025$ mol

not NaOH ← excess

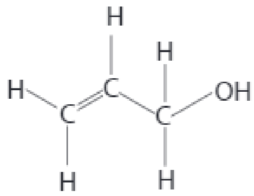
$\Delta H = \frac{1.4212}{0.025} = 56.848$ kJmol^{-1}

as exothermic → negative

$\boxed{\Delta H = -56.8 \text{ kJmol}^{-1}}$

Total for Question 3 = 5 marks

6 Prop-2-en-1-ol is an unsaturated alcohol with the structure shown.



(a) A student planned to use bond enthalpy data to calculate a value for the enthalpy change of combustion of prop-2-en-1-ol.

(i) When researching the bond enthalpy data, the student claimed that it was not necessary to find the value for the C=C bond as they could use the value for a C–C bond and multiply it by two.
Explain why the student is **incorrect**.

(2)

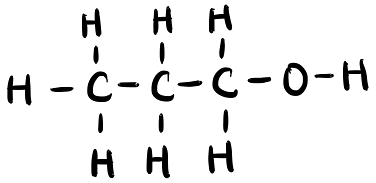
The bond in the C-C is a sigma bond, whereas in C=C there is one sigma bond and one pi bond. The pi bond has lower bond enthalpy than sigma bond as it is a weaker bond. Thus C=C is weaker / has lower bond enthalpy than double C-C.

(ii) Calculate a value for the enthalpy of combustion of prop-2-en-1-ol using the data shown.

$$C_3H_6O(g) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(g)$$

Bond	C–C	C=C	C–O	C=O	O–H	C–H	O=O
Bond enthalpy / kJ mol^{-1}	347	612	358	805	464	413	498

(3)



$+ 4 O=O \rightarrow 3\ O=C=O + 3\ H-O-H$

7 C-H
C-O $\quad + 4 O=O \rightarrow 6 C=O + 6 O-H$
O-H
2 C-C

$(7 \times 413 + 358 + 464 + 2 \times 347) + (4 \times 498) \longrightarrow (6 \times 805) + (6 \times 464)$

$6399 \longrightarrow 7614$

$\Delta H = 6399 - 7614$

$= -1215 \text{ kJ mol}^{-1}$

(iii) Explain, in terms of entropy, why the combustion of prop-2-en-1-ol is always feasible in the gaseous state.

(2)

In the gaseous state, the entropy increased after reaction as the number of moles increased. (5 moles on the left and 6 moles on the right) Thus ΔS is increased.

Total for Question 6 = 7 marks

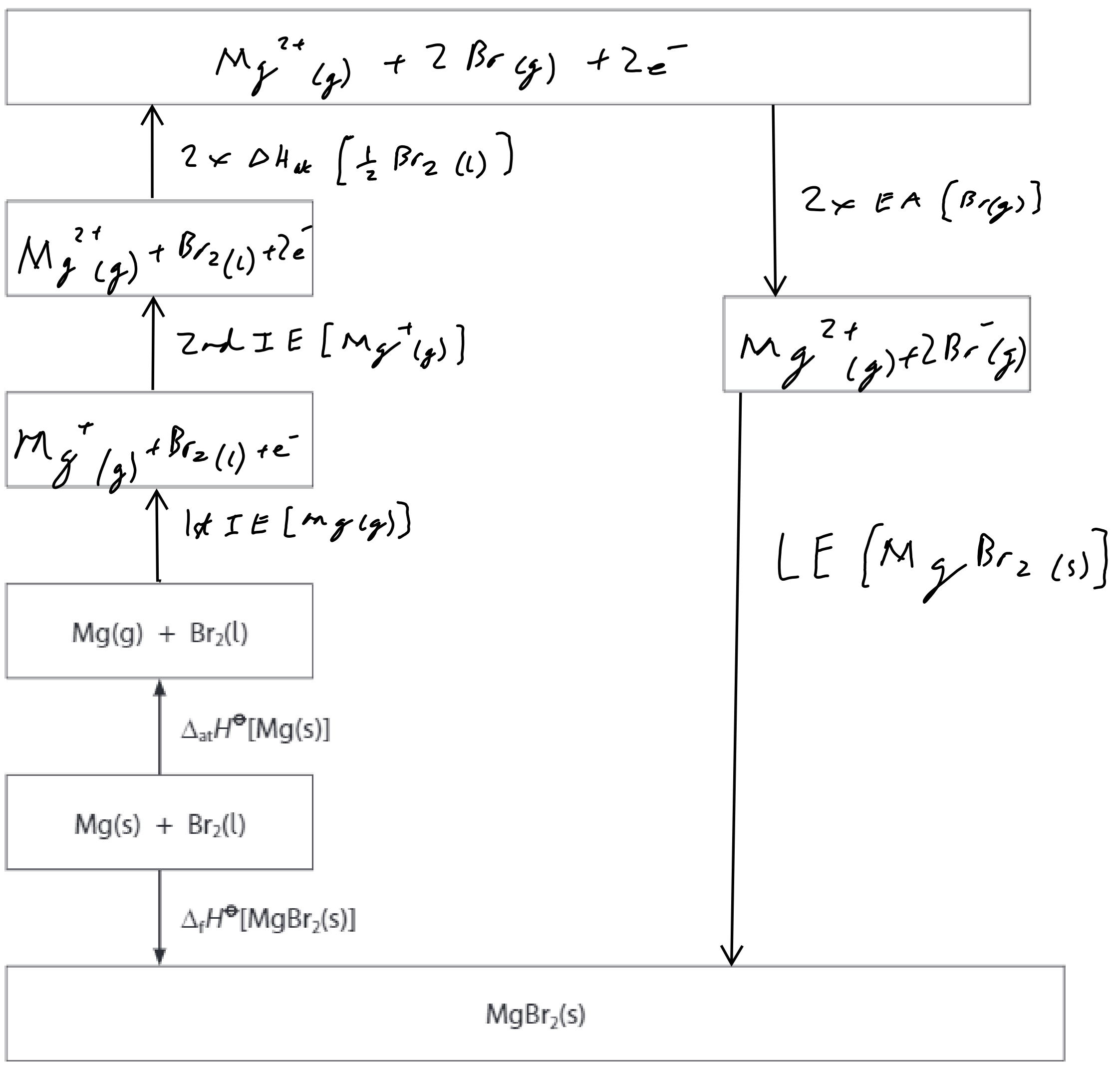
6 Magnesium bromide, $MgBr_2$, is an ionic compound.

(b) The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

Enthalpy change	**Value / kJ mol^{-1}**
enthalpy change of atomisation of magnesium, $\Delta_{at}H^{\ominus}[Mg(s)]$	+148
1st ionisation energy of magnesium, 1st IE[Mg(g)]	+738
2nd ionisation energy of magnesium, 2nd IE[$Mg^+(g)$]	+1 451
enthalpy change of atomisation of bromine, $\Delta_{at}H^{\ominus}[\frac{1}{2}Br_2(l)]$	+112
lattice energy of magnesium bromide, LE[$MgBr_2(s)$]	−2 440
enthalpy change of formation of magnesium bromide, $\Delta_{f}H^{\ominus}[MgBr_2(s)]$	−524

(i) Complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale.

(3)



(ii) Calculate the first electron affinity of bromine, in kJ mol^{-1}.

(2)

$-524 = 148 + 738 + 1451 + 2(112) + 2x + -2440$

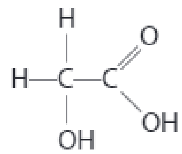
$-524 = 121 + 2x$

$x = -322.5$ kJ mol^{-1}

Total for Question 6 = 5 marks

8 2-Hydroxyethanoic acid, also known as glycolic acid, $CH_2OHCOOH$, is an alpha hydroxy acid used in some skincare products.
It has a K_a value of 1.5×10^{-4} mol dm^{-3}.

The structure of glycolic acid is



(a) A solution of glycolic acid of concentration 0.1 mol dm^{-3} has a pH of 2.4

What is the approximate pH of the resulting solution after it has been diluted by a factor of 100?

(1)

☐ **A** 1.4

☐ **B** 2.4

☒ **C** 3.4

☐ **D** 4.4

$\sqrt{1.5\times10^{-4} \times 0.001}$

$= 3.87298 \times 10^{-4} = [H^+]$

$pH = 3.41$

(b) Another solution of glycolic acid has a pH of 2.0

Calculate the concentration of this solution.

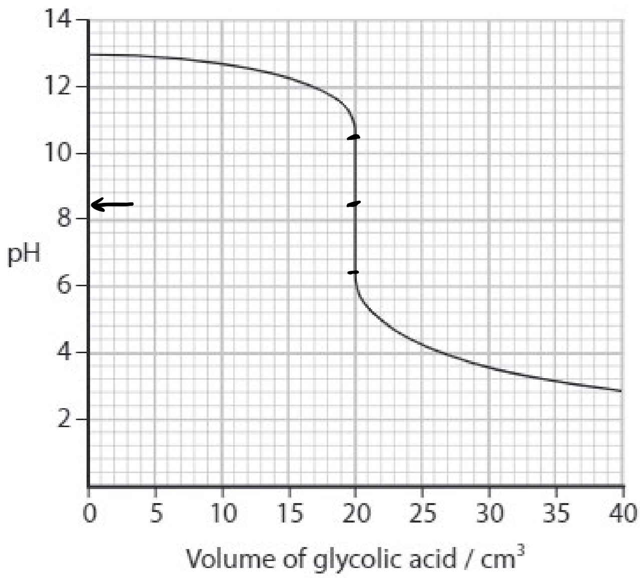
(3)

$[H^+] = 10^{-pH} = 10^{-2} = 0.01$

$K_a = \frac{[H^+]^2}{[HA]} \Rightarrow [HA] = \frac{[H^+]^2}{K_a} = \frac{0.01}{1.5\times10^{-4}}$

$= 0.667$ mol dm^{-3}

(c) The titration curve for adding glycolic acid to 25.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide is shown.



(i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection.

(3)

Phenolphthalein (in ethanol) - red → colourless

This indicator will change colour in the (vertical) very steep section of the graph

(ii) What is the concentration of this glycolic acid in mol dm^{-3}?

(1)

☐ **A** 0.080

☐ **B** 0.100

☒ **C** 0.125

☐ **D** 0.250

$$\text{moles} = \frac{0.1 \times 25}{1000} = 2.5 \times 10^{-3}$$

$$2.5 \times 10^{-3} = \frac{C \times 20}{1000}$$

$$C = 0.125$$

(iii) The pH of the solution containing just sodium glycolate and water is

(1)

read off from graph

☐ **A** 2.8

☐ **B** 6.0

☒ **C** 8.3

☐ **D** 11.0

(d) Glycolic acid has an acid dissociation constant of 1.5×10^{-4} mol dm^{-3} compared with a value of 1.7×10^{-5} mol dm^{-3} for ethanoic acid.

(i) Give a possible explanation as to why the value of K_a for glycolic acid is approximately ten times larger than that of ethanoic acid.

(2)

The oxygen in the extra hydroxyl group of glycolic acid attracts electrons and stabilises the anion. This weakens the O–H bond thus the H^+ dissociates more easily → larger K_a.

(ii) Complete the equation to show the conjugate acid-base pairs that would be produced when pure samples of glycolic acid and ethanoic acid are mixed.

(1)

$CH_2OHCOOH + CH_3COOH \rightarrow CH_2OHCOO^- + CH_3COOH_2^+$

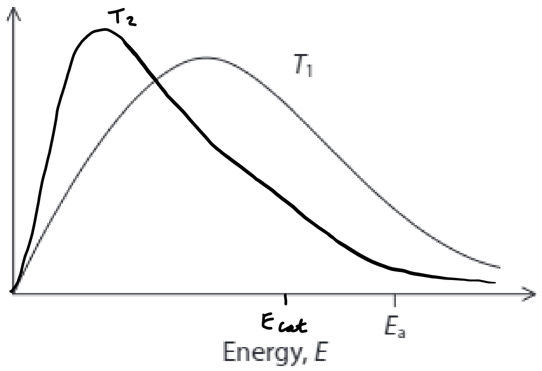
(Total for Question 8 = 12 marks)

9 This question is about the effect of temperature on the rate of decomposition of nitrogen(V) oxide.

$$2N_2O_5(g) \rightarrow 2N_2O_4(g) + O_2(g)$$

(a) The diagram shows the Maxwell-Boltzmann distribution of molecular energies for nitrogen(V) oxide at a temperature T_1.

E_a is the activation energy of this reaction.



(i) Give the label for the vertical axis.

(1)

Number of molecules

(ii) Draw a second curve on the same set of axes for the same gas at a **lower** temperature, T_2.

(2)

(iii) Explain, in terms of collisions and energy, why lowering the temperature decreases the rate of reaction.

(2)

Lowering the temperature decreases the average kinetic energy of the particles. This decreases the frequency of collisions. It also decreases the proportion of particles that have energy greater than activation energy. These factors decrease the rate of successful collisions, and so decrease the rate of reaction.

(iv) A catalyst is added to the gas.

Label the diagram above with the symbol E_{cat} to show a possible activation energy for the reaction in the presence of a catalyst.

(1)

(b) The rate constant for the decomposition of nitrogen(V) oxide was determined at two temperatures.

Temperature / K	Rate constant / s^{-1}
328	1.50×10^{-3}
338	4.87×10^{-3}

Calculate the activation energy for this reaction.

Include units and give your answer to an appropriate number of significant figures.

You should **not** attempt to use any graphical method to answer this question.

The Arrhenius equation relating two rate constants, k_1 and k_2, at two different temperatures, T_1 and T_2, can be expressed as

$$\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

(5)

$$\Rightarrow \ln\left(\frac{4.87\times10^{-3}}{1.50\times10^{-3}}\right) = -\frac{E_a}{8.31}\left(\frac{1}{338} - \frac{1}{328}\right)$$

$$\frac{-E_a}{8.31} = -13056$$

$$E_a = 108492 \text{ J}$$

$$= 108 \text{ kJ}$$

(Total for Question 9 = 11 marks)

Total for Test = 40 marks