Sydney Girls High School

Student Number

2020

YEAR 11

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 60 minutes
- Write using black pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- Two pages of data sheets and a Periodic Table are provided
- Write your student number on the multiple choice answer sheet and on each booklet

Total marks – 35

Part A – Pages 2-6
10 marks

- Attempt Questions 1 – 10

Part B – Pages 7-11
25 marks

- Attempt Questions 11 – 15

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Part A – 10 marks
Attempt Questions 1 – 10

Use the multiple-choice answer sheet for Questions 1–10

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1 When a metal reacts with acid, the products are:

(A) A salt and water

(B) A salt and hydrogen gas

(C) A salt, carbon dioxide and oxygen gas

(D) A salt, carbon dioxide and hydrogen gas

Questions 2 and 3 refer to the following scenario:

Calcium metal that is exposed to the air forms and oxide coating.

2 What is the oxidation number of the oxide ion in calcium oxide?

(A) -2

(B) 0

(C) 2

(D) +2

3 Which species has been reduced in this reaction?

(A) Air

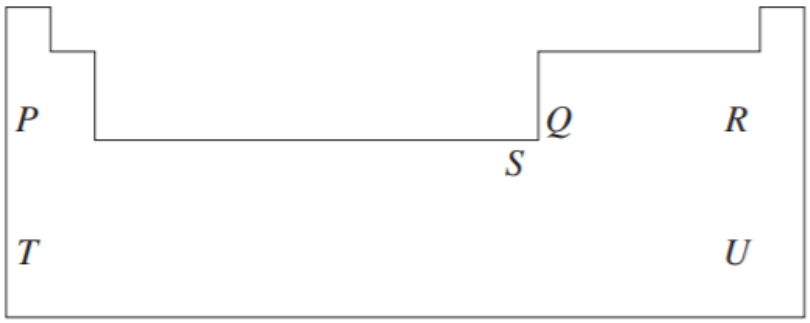
(B) Calcium

(C) Oxygen

(D) Calcium oxide

Questions 4 and 5 refer to the following scenario:

A representation of the Periodic Table is shown. The positions of six different elements, P, Q, R, S, T and U are given.



4 Which element is most likely to be the most reactive metal?

(A) T

(B) P

(C) S

(D) Q

5 Which element has the highest first ionisation energy?

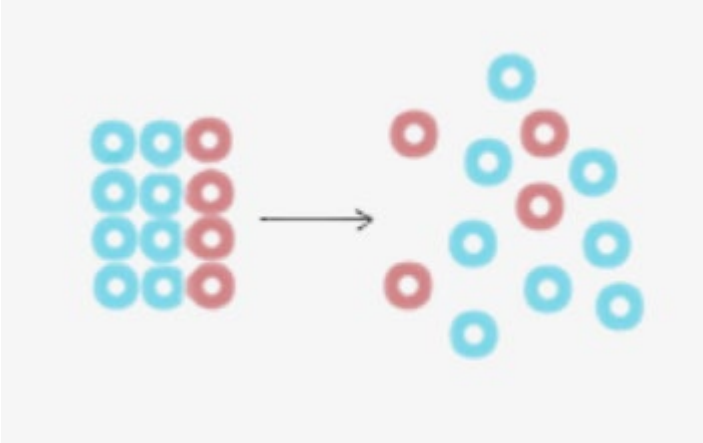
(A) P

(B) R

(C) T

(D) U

6 Models are used in chemistry to illustrate phenomena. What is the diagram below modelling an increase in?



(A) Gibbs free energy

(C) Entropy

(D) Spontaneity

7 What is the minimum temperature above which the following reaction becomes spontaneous?

$$ZnCO_{3(s)} \rightarrow ZnO_{(s)} + CO_{2(g)}$$

$\Delta H^{o} = +71$ kJ mol^{-1} and $\Delta S^{o} = +176$ J mol^{-1}.K^{-1}.

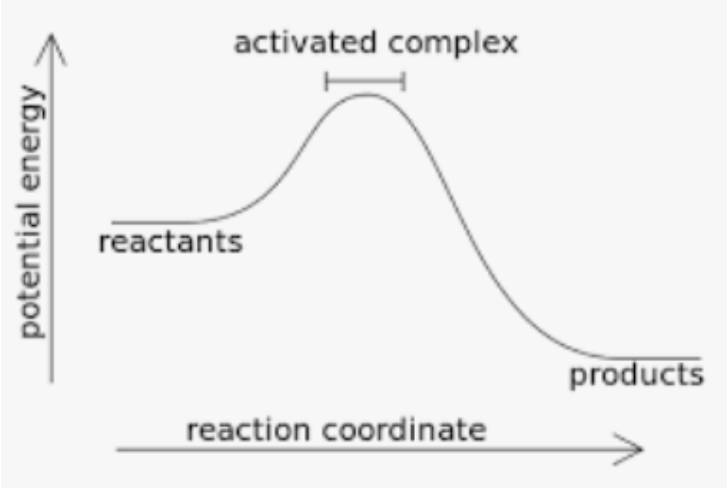
(A) 130 ^{o}C

(B) 400 ^{o}C

(C) 200 K

(D) 600 K

8 How will the energy profile diagram for a reaction below change if a catalyst is added to the reaction mixture?



(A) The energy of the reactants will be lower, causing the rate of reaction to increase

(C) The energy of the products will be lower, causing the rate of reaction to increase

(D) The energy of the activated complex will be lower, causing the rate of reaction to increase

9 The process of photosynthesis has a ΔH of +2803 kJ mol^{-1}. The standard entropies of formation of the substances involved in photosynthesis are:

Substance	S^o (J $mol^{-1}.K^{-1}$)
CO_2	214
H_2O	70
$C_6H_{12}O_6$	209.2
O_2	205

At what temperatures is photosynthesis spontaneous?

(A) All temperatures

(B) Above temperatures around 300K

(C) Below temperatures around 300K

(D) Photosynthesis is never spontaneous

10 The heats of combustion of C(s, graphite), $H_2(g)$ and $CH_4(g)$ at 298 K and 1 atm are respectively −393.50 kJ mol^{-1}, −285.83 kJ mol^{-1} and −890.36 kJ mol^{-1}. What is the enthalpy of formation for CH_4?

(A) +211.03 kJ mol^{-1}

(B) -74.80 kJ mol^{-1}

(C) -211.03 kJ mol^{-1}

(D) -1569.69 kJ mol^{-1}

Student Number

Part B – 25 marks

Attempt Questions 11 - 15

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 11 (4 marks)

When copper carbonate ($CuCO_3$) is heated, copper(II) oxide (CuO) and carbon dioxide (CO_2) form.

a) Write a balanced chemical equation for the reaction. **1**

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b) Calculate the mass of copper carbonate heated when the mass of gas produced was 0.12 g. **2**

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c) Identify two signs that a chemical reaction has taken place. **1**

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Question 12 (5 marks)

a) Write a full chemical equation for the precipitation reaction between silver nitrate and sodium iodide. **1**

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b) Identify the spectator ions in the reaction. **1**

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c) If 10.0 mL of 1.0 mol L^{-1} silver nitrate is added to 10.0 mL of 1.0 mol L^{-1} sodium iodide, calculate the mass of silver iodide produced. **3**

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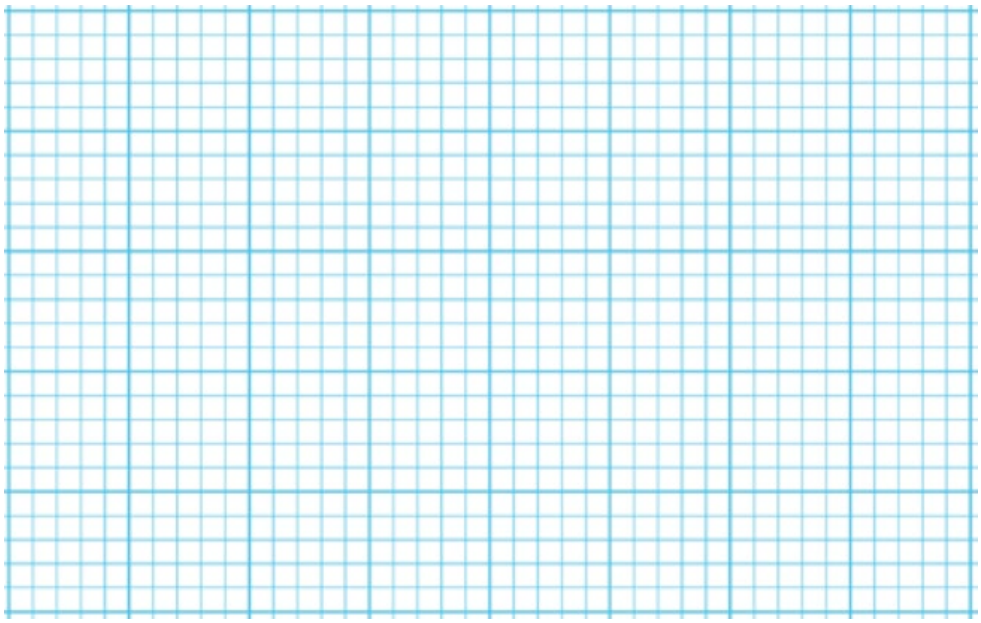
Question 13 (9 marks)

10.04 g of marble chips ($CaCO_3$) was weighed onto a piece of paper. 100mL of 1 mol L^{-1} HCl was added to a conical flask and placed on an electronic balance. The marble chips were then added to the balance and the balance was zeroed. The mass of CO_2 gas escaping was measured every 30 seconds by measuring the mass fall of the contents of the flask.

Time (s)	0	30	60	90	120	150	180	210	240
Mass of CO_2 (g)	0	1.15	1.55	1.80	2.05	2.15	2.20	2.20	2.20

a) Graph the information above on the grid below. **3**



b) Determine the limiting reagent in this experiment. Use calculations to support your answer. **3**

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c) Explain the shape of the curve. **3**

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Question 14 (2 marks)

Use the following bond energies to calculate the enthalpy change for the reaction between hydrogen and fluorine to make hydrogen fluoride.

$$H_{2(g)} + Br_{2(g)} \rightarrow 2HBr_{(g)}$$

Bond	Average Bond Energy ($kJ.mol^{-1}$)
H-H	436
Br-Br	193
H-Br	366

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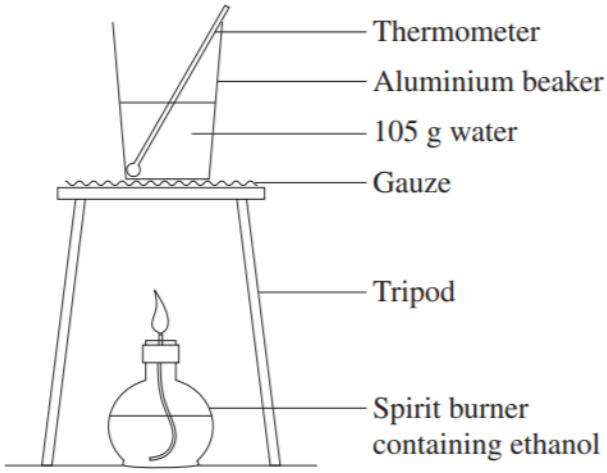
Question 15 (5 marks)

a) The following apparatus was used in an experiment to determine the molar enthalpy of combustion of ethanol (C_2H_5OH).



Calculate the experimental molar enthalpy of combustion *($\Delta_c H$)* of ethanol if 0.470 g ethanol was burned to raise the water temperature from 18.5°C to 32.5°C. **4**

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b) The theoretical value of $\Delta_c H$ for ethanol is -1368 kJ mol^{-1}. Describe one improvement, in a school laboratory, you could make to the experiment to make it more accurate. **1**

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End of Examination

Sydney Girls High School

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25 marks

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Part A – 10 marks
Attempt Questions 1 – 10

Use the multiple-choice answer sheet for Questions 1–10

---

1 When a metal reacts with liquid water, the products are:

(A) Metal hydroxide and oxygen gas

(B) Metal hydroxide and hydrogen gas

(C) Metal oxide and oxygen gas

(D) Metal oxide and hydrogen gas

Questions 2 and 3 refer to the following scenario:

Calcium metal that is exposed to the air forms and oxide coating.

2 What is the oxidation number of the oxide ion in calcium oxide?

(A) -2

(B) 0

(C) 2

(D) +2

3 Which species has been reduced in this reaction?

(A) Air

(B) Calcium

(C) Oxygen

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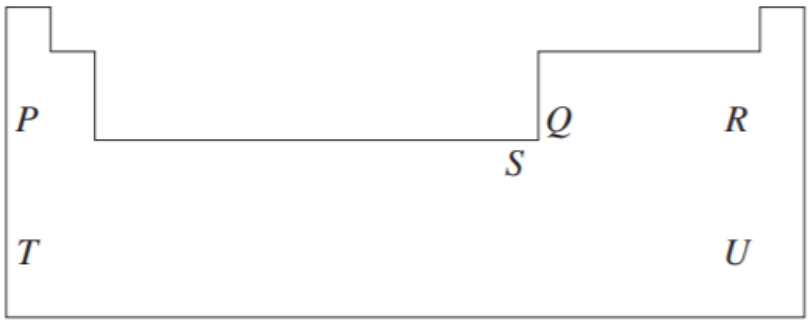
Questions 4 and 5 refer to the following scenario:

A representation of the Periodic Table is shown. The positions of six different elements, P, Q, R, S, T and U are given.



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(C) S

(D) Q

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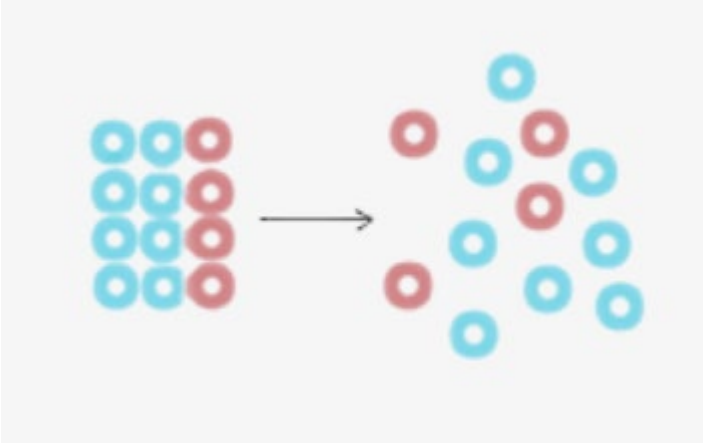
6 Models are used in chemistry to illustrate phenomena. What is the diagram below modelling an increase in?



(A) Gibbs free energy

(C) Entropy

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$\Delta H^o = +71$ kJ mol^{-1} and $\Delta S^o = +176$ J mol^{-1}.K^{-1}.

(A) 130 ºC

(B) 400 ºC

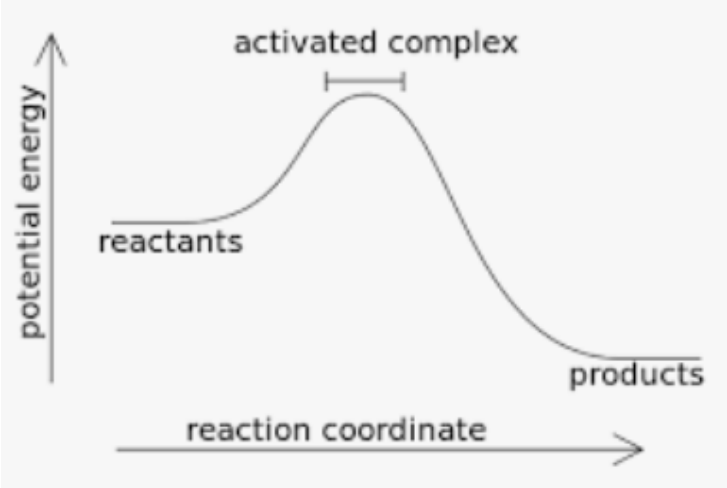
(C) 200 K

(D) 600 K

For a reaction to be spontaneous, ΔG^o must be negative. Let's make ΔG^o a very small number and solve for T:

$\Delta G = \Delta H - T\Delta S$
-0.0001 kJ = + 71 kJ mol^{-1} – T. 176 J mol^{-1}K^{-1}
T = 403.408 K (130ºC)

8 How will the energy profile diagram for a reaction below change if a catalyst is added to the reaction mixture?



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9 The process of photosynthesis has a ΔH of +2803 kJ mol^{-1}. The standard entropies of formation of the substances involved in photosynthesis are:

Substance	S^o (J $mol^{-1}.K^{-1}$)
CO_2	214
H_2O	70
$C_6H_{12}O_6$	209.2
O_2	205

At what temperatures is photosynthesis spontaneous?

(A) All temperatures

(B) Above temperatures around 300K

(C) Below temperatures around 300K

(D) Photosynthesis is never spontaneous

The question stem tells us that ΔH is positive, so this is not favourable. We need to determine ΔS. Remember to write your balanced chemical equation first, so that you use the correct co-efficients.

$6CO_2\,(g) + 6H_2O\,(l) \longrightarrow C_6H_{12}O_6\,(aq) + 6O_2\,(g)$

$\Delta S = \Sigma S°(\text{products}) - \Sigma S°(\text{reactants})$

$= [209.2 + (6 \times 205)] - [(6 \times 214) + (6 \times 70)]$

$= -264.8\ \text{J mol}^{-1}\text{K}^{-1}$

A negative entropy value, combined with a positive enthalpy value, means that this reaction is never spontaneous. In fact, its reverse is spontaneous.

10 The heats of combustion of C(s, graphite), $H_2(g)$ and $CH_4(g)$ at 298 K and 1 atm are respectively −393.50 kJ mol^{-1}, −285.83 kJ mol^{-1} and −890.36 kJ mol^{-1}. What is the enthalpy of formation for CH_4?

(A) +211.03 kJ mol^{-1}

(B) -74.80 kJ mol^{-1}

(C) -211.03 kJ mol^{-1}

(D) -1569.69 kJ mol^{-1}

$C\,(s) + O_2\,(g) \longrightarrow CO_2\,(g)$ $\quad \Delta H° = -393.50\ \text{kJ mol}^{-1}$

$2 \times H_2\,(g) + ½\,O_2\,(g) \longrightarrow 2H_2O\,(l)$ $\quad \Delta H° = -571.66\ \text{kJ mol}^{-1}$

$CO_2\,(g) + 2H_2O\,(l) \longrightarrow CH_4\,(g) + 2\,O_2\,(g)$ $\quad \Delta H° = +890.36\ \text{kJ mol}^{-1}$

$C\,(s) + \cancel{O_2\,(g)} + 2\,H_2\,(g) + \cancel{O_2\,(g)} + \cancel{CO_2\,(g)} + \cancel{2H_2O\,(l)} \longrightarrow \cancel{CO_2\,(g)} + \cancel{2H_2O\,(l)} + CH_4\,(g) + \cancel{2\,O_2}$

$C\,(s) + 2H_2\,(g) \longrightarrow CH_4\,(g)$ $\quad \Delta H° = -74.8\ \text{kJ mol}^{-1}$

Student Number

Part B – 25 marks

Attempt Questions 11 - 15

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 11 (4 marks)

When copper carbonate ($CuCO_3$) is heated, copper(II) oxide (CuO) and carbon dioxide (CO_2) form.

a) Write a balanced chemical equation for the reaction.

Criteria	Marks
• Correct equation, including states	1

$CuCO_3\ (s) \longrightarrow CaO\ (s) + CO_2\ (g)$ **1**

b) Calculate the mass of copper carbonate heated when the mass of gas produced was 0.12 g. **2**

Criteria	Marks
• Correct calculation, including units	2
• Substantially correct calculation	1

$n\ (CO_2) = \frac{m}{MM}$

$= \frac{0.12\ g}{44.01\ gmol{-}1}$

$= 0.0027$ mol CO_2

From balanced chemical equation, $n\ (CuCO_3) = n\ (CO_2) \therefore n\ (CuCO_3) = 0.0027$ mol

$m\ (CuCO_3) = nMM$

$= 0.0028 \text{ mol} \times 123.56 \text{ g mol}^{-1}$

$= 0.34$ g (2 s.f.)

Marker feedback:

Be careful with your handwriting when you write your state symbols- 's' and 'g' can look very similar. I gave the benefit of the doubt!

Please ensure that you are using the correct molecular weights off the periodic table that you are provided. I was generous throughout the exam with calcs that were done with e.g. H as 1 rather than 1.008, but from hereon in you will be penalised, just as you will in the HSC.

c) Identify two signs that a chemical reaction has taken place. **1**

Criteria	Marks
• Two signs listed	1

A change in colour; an odour is produced; bubbling or fizzing, indicating the formation of a gas; a precipitate is formed; there is a change in temperature (heat has been absorbed or released); change in pH

Marker feedback:

Did not pay 'a new substance is formed'. That's too vague, especially given that this dot point appears in both Stage 4 and Stage 5.

Question 12 (5 marks)

a) Write a full chemical equation for the precipitation reaction between silver nitrate and sodium iodide. **1**

Criteria	Marks
• Correct equation, including states	1

$AgNO_3\,(aq) + NaI\,(aq) \longrightarrow NaNO_3\,(aq) + AgI\,(s)$

Marker feedback:

States are vital *here, otherwise how do you know that it's a precipitation reaction? Many of us thought that silver had an oxidation state of +2. Silver does display higher oxidation numbers (+2 and +3) but it's vanishingly rare and the chemistry is wacko. Read more here:*

Chemistry of silver(II): a cornucopia of peculiarities†

You will need to know that silver is +1 for the HSC. Also, no parentheses needed for radicals (complex ions) if there's only one e.g. $AgNO_3$ not $Ag(NO_3)$

b) Identify the spectator ions in the reaction. **1**

Criteria	Marks
• Correctly identifies spectator ions	1

NO_3^- , Na^+

c) If 10.0 mL of 1.0 M silver nitrate is added to 10.0 mL of 1.0 M sodium iodide, calculate the mass of silver iodide produced. **3**

Criteria	Marks
• Correct calculation, including units	3
• Substantially correct calculation	2
• Some relevant information	1

From balanced chemical equation, n (Ag^+) = n (I^-).

n (Ag^+) = cV

= 1.0 mol L^{-1} × 0.01 L

= 0.01 mol Ag^+
∴ 0.01 mol AgI forms

m (AgI) = nMM

= 0.01 mol × 234.8 g mol^{-1}

=2.3 g (2 s.f.)

Marker feedback:

Too many of us did not use the formula $c = \frac{n}{V}$, and tried to divide the volume by the molar mass. This was also an issue in the next question. You needed to show me how you knew that the moles of silver iodide was 0.1 as well. Carry-over errors from the equation (e.g. thinking that silver was +2) were not penalised, if you're wondering why you may have full marks for the wrong answer!

Question 13 (9 marks)

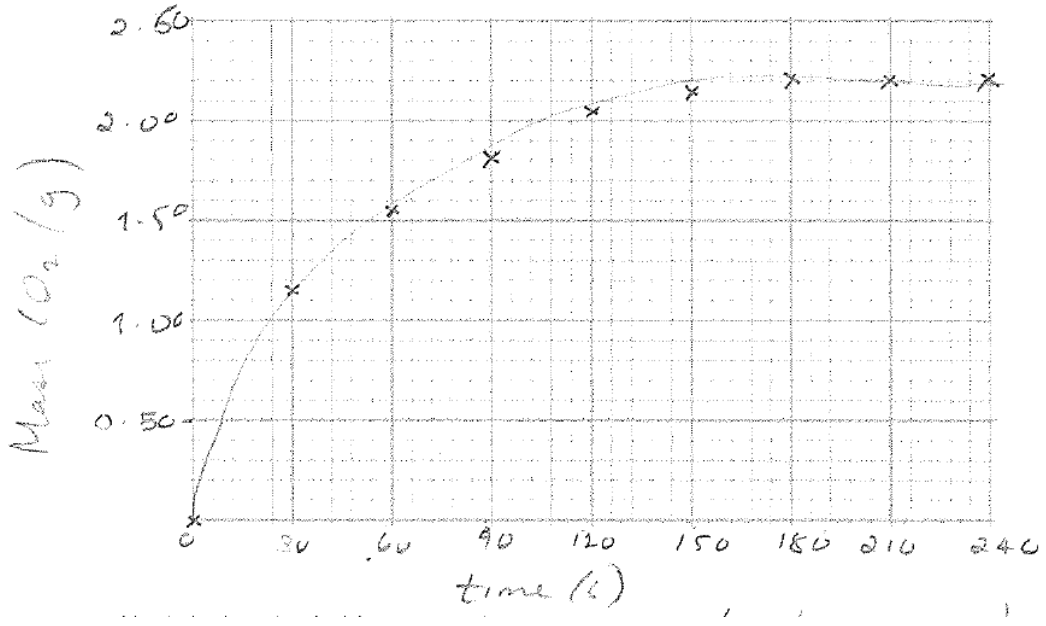
10.04 g of marble chips ($CaCO_3$) was weighed onto a piece of paper. 100mL of 1M HCl was added to a conical flask and placed on an electronic balance. The marble chips were then added to the balance and the balance was zeroed. The mass of CO_2 gas escaping was measured every 30 seconds by measuring the mass fall of the contents of the flask.

Time (s)	0	30	60	90	120	150	180	210	240
Mass of CO_2 (g)	0	1.15	1.55	1.80	2.05	2.15	2.20	2.20	2.20

a) Graph the information above on the grid below. **3**

Criteria	**Marks**
● Data points correct ● Fully labelled axes, including appropriate units ● Using > 75% of grid (appropriate linear scale used) ● Appropriate line of best fit (not above 2.2g)	3
● As above but with one omission/error	2
● As above but with 2 omissions/errors	1

a) Graph the information above on the grid below.



Marker feedback:

Not too badly done. A really common error was to omit the 0 s data point- why? In terms of general graphing feedback:

- *Don't redraw the axes. In the HSC, as in here, we gave you a beautifully sized piece of grid paper, perfect for your scale to go up by reasonable increments. This also prevents you from using the around 75% (at least) of the grid that you're expected to. You will lose marks for this.*
- *Please don't use wacky increments, markers are tired and we don't to have to assiduously check your graph because you went up by 16.5 increments when everyone else did 20. Also, many people chose to use the 30, 60, 90 etc but did it on every fourth line (rather than the fifth, major gridline). I am mystified by this.*
- *If you do want to start the axes at non-zero values, you need to specify this. You can't just start at 1.0 and then go up by 0.5 increments. Also, there was no reason to do this here.*
- *Bring a pencil! You didn't lose marks for pen but it makes it really hard if you make a mistake. In related advice, bring a sharpener! Some of the pencil lines were thick enough to obscure your data points, and that caused you to lose marks*
- *Using crosses is the best way to show your data points. Carefully mark the spot with small dot, then draw a small but clear x over the top.*
- *Don't forget labels and units, and remember independent on the x-axis and dependent on the y-axis.*

b) Determine the limiting reagent in this experiment. Use calculations to support your answer.

Criteria	Marks
• Correct determination of limiting reagent, including application of stoichiometric ratio from balanced chemical equation	3
• Substantially correct calculation	2
• Some relevant information	1

$2HCl\ (aq) + CaCO_3\ (s) \longrightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$ **3**

$n\ (CaCO_3) = \frac{m}{MM}$

$= \frac{10.04\ g}{100.09\ gmol{-}1}$

= 0.1003 mol $CaCO_3$

n (HCl) = cV

= 1.0 mol L^{-1} × 0.1 L

= 0.1 mol HCl

From balanced chemical equation, n (HCl) : n ($CaCO_3$) = 2:1 ∴ HCl is limiting

Marker feedback:

As above, too many of us did not use the formula $c = \frac{n}{V}$, *and tried to divide the volume by the molar mass. It wasn't enough to tell me that HCl was limiting- you needed to apply stoichiometric ratios, otherwise how could I know that you knew that HCl was limiting not just because there was slightly less of it than the* $CaCO_3$*? You needed, as ever, a balanced chemical equation to start you off. Be really careful about rounding too early, too, and ensure that you use MM from the periodic table.*

This question told you to support your answer with calculation- too many of us did not show full working. You must ALWAYS show full working e.g. just telling me that the concentration of HCl was 0.1? How did I know that you'd done a calculation? Also, please please please don't give me an answer in fractions.

c) Explain the shape of the curve. **3**

Criteria	**Marks**
• Correct explanation of the shape of the curve, including initial rise and decrease in rate and cessation of gas production	3
• Describes graph, but omits some features	2
• Identifies some features of the graph	1

Initially the curve is steep, as the $CaCO_3$ is steep, as the calcium carbonate ad hydrochloric acid react generating CO_2 quickly. Then, as more and more HCl has reacted, there are fewer hydronium molecules, they collide less frequently with the calcium carbonate and the reaction rate slows meaning that the mass of the CO_2 being produced is lower, so the curve becomes

flatter. Eventually, all of the HCl has reacted and the CO_2 production ceases, and the line plateaus.

The mass of CO_2 increases rapidly in the first 30s, gradually slows down its increase 30s to 180s and remains constant after 180s. The initial rapid production of CO_2 gas is when the concentration of acid is greatest. As the concentration falls, the rate of reaction decreases. At 180s there is no production of CO_2 because [HCl] = 0.

Marker feedback:

Explain means relate cause and effect. The best answers describe key features of the curve, and then explained them in terms of the chemistry. There were a lot of mathematics terms being used here, but I'm a chemistry teacher and that's what I want to hear about.
Be careful of throwing in terms that you don't understand- there were a few references to particular concepts that we have coming up in Year 12; the problem is, if you use a term that you're only half familiar with, then you'll likely mis-apply it, and I will have to deduct marks.

Question 14 (2 marks)

Use the following bond energies to calculate the enthalpy change for the reaction between hydrogen and fluorine to make hydrogen fluoride.

$$H_{2(g)} + Br_{2(g)} \rightarrow 2HBr_{(g)}$$

Bond	Average Bond Energy ($kJ.mol^{-1}$)
H-H	436
Br-Br	193
H-Br	366

Criteria	Marks
• Correct calculation, including units	2
• Substantially correct calculation	1

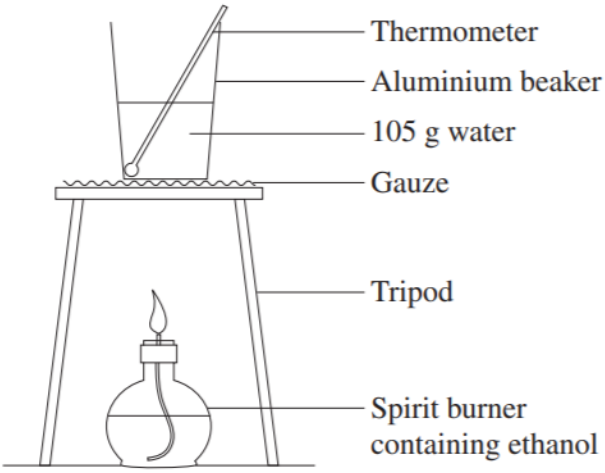
Bonds broken: + 436
+ 193
Bonds formed: 2 × -366
= -103 kJ mol^{-1}

Marker feedback:

Most common problem here was wrong sign.

Question 15 (5 marks)

a) The following apparatus was used in an experiment to determine the molar enthalpy of combustion of ethanol (C_2H_5OH).



Calculate the experimental molar enthalpy of combustion (Δ_cH) of ethanol when 0.47 g ethanol was used to raise the water temperature from 18.5°C to 32.5°C. **4**

Criteria	Marks
• Correct calculation, including significant figures	4
• Substantially correct calculation	3
• Two relevant calculations	2
• Some relevant information	1

$n\ (EtOH) = \frac{m}{MM}$

$= \frac{0.470g}{46.068\ gmol{-}1}$

$= 1.02 \times 10^{-2}$ mol EtOH

$q = mc\Delta T$

$= 105g \times 4.18\ J\ g^{-1}K^{-1} \times (305.5\ K - 291.5K)$

$= 6144.6\ J$

$\Delta H = \frac{q}{n}$

$= \frac{6144.6\ J}{1.02 \times 10{-}2\ \text{mol}}$

= -602.2 kJ mol^{-1}
= -602 kJ mol^{-1} (3 s.f.)

Marker feedback:
This was well done. Sig figs needed here. Please show all your working! A relatively common mistake that took people from 4 to 2 was using the mass of alcohol rather than water. That's a serious error, and something to look out for in future.

b) The theoretical value of $\Delta_c H$ for ethanol is -1368 kJ mol^{-1}. Describe one improvement, in a school laboratory, you could make to the experiment to make it more accurate. **1**

Criteria	Marks
• Valid improvement	1

Rather than having the calorimeter sitting on a gauze mat, a retort stand and clamp can be used.

Marker feedback:
So many of us said lid, but the question has given you a stimulus for a reason. Please look at it!
The spirit burner is miles away from the calorimeter, and the calorimeter is sitting on a gauze mat. Fixing any one of those would improve results.
No to the lid, anyways. A metal lid isn't that great, and will prevent you from stirring and having a thermometer in there. And suggesting that we could use Styrofoam? Near an open flame? Nooooo. Polystyrene burns to release styrene gas which is carcinogenic; furthermore your body goes on and metabolises it to styrene oxide which is toxic, mutagenic and carcinogenic. Never, ever let polystyrene anywhere near an open flame!

End of Examination