Mark Scheme - 1.3 Chemical Calculations

1. (a) (i) $2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_2H_5OH(l)$ (state symbols needed)

C(s) allowed as C(gr) or C(graphite) [1]

(ii) (if these elements were reacted together) other products would form/ carbon does not react with hydrogen and oxygen under standard conditions [1]

(b) (i) energy = 100 × 4.2 × 54 =22680 [1]

(ii) moles ethanol = 0.81/46 = 0.0176 (1)

energy change = $\frac{22.68}{0.0176}$ $\Delta H = -1290$ (1)

–ve sign and correct to 3 sf (1) [3]

(c) internet value numerically larger (1)

heat losses / incomplete combustion / thermal capacity of calorimeter ignored (1) no credit for energy loss [2]

(d) (i) $C_3H_7OH + 4\frac{1}{2}O_2 \rightarrow 3CO_2 + 4H_2O$ (ignore state symbols) [1]

(ii) negative enthalpy change means energy in bonds broken is less than that in bonds made [1]

(iii) more bonds broken and made in propanol and therefore more energy released [1]

(e) any 4 from:

both conserve carbon / non-renewable fuel sources / fossil fuels / use renewable sources

(these gas / liquid) suitable for different uses e.g. ethanol to fuel cars

atom economy gasification is less (some C lost as CO_2) / CO_2 produced in gasification is a greenhouse gas

CO is toxic

gasification at high temperature / enzymes need low temperature

enzyme approach therefore saves fuel / gasification needs more energy [4]

3 max if any reference to destruction of ozone layer

QWC [2]
The candidate has selected a form and style of writing that is appropriate to purpose and complexity of the subject matter (1)

Answer has suitable structure (1)

Total [17]

2.

(a)

	1	2	3	4
Volume used / cm^3	20.75	20.20	20.10	20.30

[1]

(b) 20.20 cm^3 [1]

3.

(a) Low temperature (1)
As temperature is decreased equilibrium moves in exothermic direction. (1)

High pressure (1)

As pressure is increased equilibrium moves towards side with smaller number of gas moles (1) [4]

QWC The information is organised clearly and coherently, using specialist vocabulary where appropriate [1]

(b) ΔHreaction = ΔH_f products – ΔH_f reactants (1)

$-46 = \Delta H_f$ ethanol – (52.3 – 242)

ΔH_f ethanol = -46 – 189.7 (1)

ΔH_f ethanol = -235.7 kJ mol^{-1} (1) [3]

(c) Bonds broken = 1648 + 612 + 926 = 3186 kJ mol^{-1} (1)

Bonds formed = 2060 + 348 + 360 + 463 = 3231 kJ mol^{-1} (1)

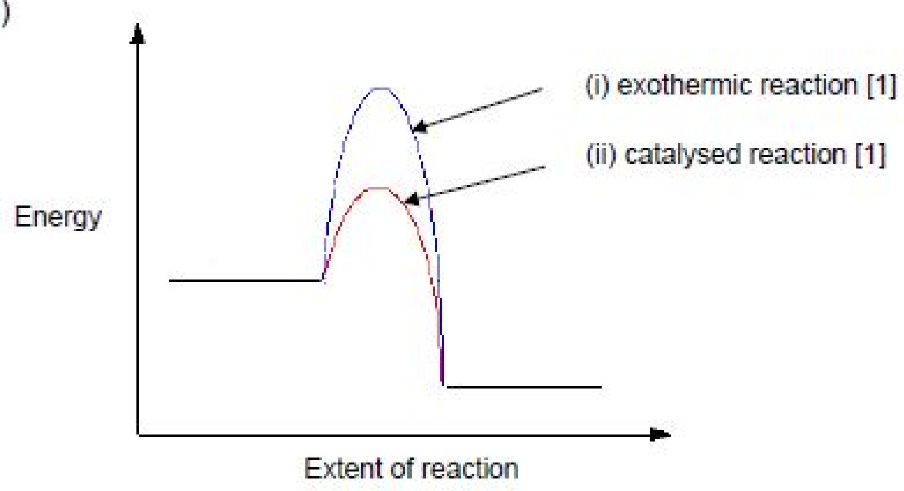
ΔH reaction = 3186 – 3231 = -45 kJ mol^{-1} (1) [3]

(d) (i) Average bond enthalpies used (not actual ones) [1]

(ii) Yes, since answers are close to each other [1]

(e) Catalyst is in different (physical) state to reactants [1]

(f)



(i) exothermic reaction [1]

(ii) catalysed reaction [1]

4.

(a)		Plotting	(2)	
		Best fit line	(1)	[3]
(b)	(i)	C	(1)	
		Curve steeper	(1)	[2]
	(ii)	Concentration of acid is greatest		[1]
(c)		44 cm^3 (±1 cm^3)		[1]
(d)		Moles Mg = 0.101/24.3 = 0.00416	(1)	
		Moles HCl = 2 x 0.02 = 0.04	(1)	[2]
(e)	(i)	Mg is not the limiting factor / Mg now in excess / HCl not in excess		[1]
	(ii)	Moles acid = 0.5 x 0.04 = 0.02	(1)	
		Volume H_2 = 0.01 x 24 = 0.24 dm^3 - correct unit needed	(1)	[2]
(f)		Lower the temperature of the acid	(1)	
		Reactants collide with less energy	(1)	
		Fewer molecules that have the required activation energy (1)		[3]
or		Use pieces of magnesium (1) less surface area (1) less chance of successful collisions (1)		

QWC Selection of a form and style of writing appropriate to purpose and to complexity of subject matter. [1]

Total [16]

5.

(a) to increase rate of reaction / to increase surface area [1]

(b) $MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$ (ignore state symbols) [1]

(c) rate starts fast and gradually slows (1)

because concentration becomes less so fewer collisions (per unit time) / less frequent collisions / lower probability of collisions (1)

at time = 17/18 min rate = 0 (1) [3]

(d) all the solid would all have disappeared / if more carbonate is added further effervescence is seen [1]

(e) (i) volume CO_2 = 200 cm^3 (1)

moles CO_2 = 200 / 24000 = 0.008333 = moles $MgCO_3$ (1)
[minimum 2 sf] [2]

(ii) mass $MgCO_3$ = 0.008333 × 84.3 = 0.702 g (1)

$\% \ MgCO_3 = \frac{0.702}{0.889} \times 100 = 79.0\% / 79\%$ [2]

(e) carbon dioxide is soluble in water / reacts with water (1)

volume collected less therefore % / moles of $MgCO_3$ less (1) [2]

(f) use of 40.3 and 84.3 (1)

atom economy = 40.3 / 84.3 × 100 = 47.8% (1) [2]

Total [14]

6.

(a)		Moles NaCl = $\frac{\underline{900}}{58.5}$ = 15.38	(1)	
		Moles Na_2CO_3 = 7.69	(1)	
		Mass Na_2CO_3 = 7.69 × 106 = 815(.4) g	(1)	[3]
(b)	(i)	2.52 g		[1]
	(ii)	Moles Na_2CO_3 = 0.02 Moles H_2O = 0.14 (1) $x = 7$	(1) (1)	[2]
(c)	(i)	Moles = 0.5 × 0.018 = 0.009		[1]
	(ii)	0.0045		[1]
	(iii)	0.0045 × 106 = 0.477		[1]
	(iv)	% = 0.477/0.55 = 86.7 %		[1]

Total [10]

7.

(a) percentage Be by mass = 5.03% (1)

division of percentage by A_r for Be and at least one other element as shown below (1)

Al 10.04 ÷ 27 = 0.3719 → 1.00

Be 5.03 ÷ 9.01 = 0.5583 → 1.50

O 53.58 ÷ 16 = 3.3488 → 9.00

Si 31.35 ÷ 28.1 = 1.1566 → 3.10

molecular formula = $Al_2Be_3O_{18}Si_6$ or x=3 (1) **[3]**

(b) (i) Hess' Law states that where a reaction can occur by more than one route the total enthalpy **change** for each route will be the same **[1]**

(ii) $\Delta H = -393.5 - (-395.4)$ (1) $= +1.9 \text{ kJ mol}^{-1}$ (1) **[2]**

(iii) Kyran is **incorrect** as diamond is not the **standard state** of carbon **[1]**

(iv) I mass of diamond = 7.30 g **[1]**

II mass of graphite = 7.30 ÷ (93/100) (1) = 7.85 g (1) **[2]**

Total [10]

8.

(a) (i) Sample is bombarded by high energy electrons / electron gun used on sample (1)
Electron knocked out (to form ions) (1) [2]

(ii) So no more than / only 1 electron is knocked out [1]

(iii) No difference (1)
Same number of electrons (in the outer shell) (1) [2]

(b) (i) $\frac{(7.25 \times 6) + (92.75 \times 7)}{100}$ (1)

6.928 (1) (accept 6.93) [2]

(ii) $^{6}Li^{+}$ since lower mass / lower m/z / lighter
do not accept 'smaller' [1]

(c) (i) $M_r(NH_4)_2SO_4 = 132.18$ (1)

Moles = 0.0156 (1) [2]

(ii) Moles LiOH = 0.0312 (1)

Concentration $= \frac{0.0312}{0.0298} = 1.05 \text{ mol dm}^{-3}$ (1) [2]

(iii) Atom economy $= \frac{34.06}{180.08} \times 100$ (1)

$= 18.9\,\%$ (1) [2]

Total [14]

9.

(a) (i) I burette / (graduated) pipette [1]

II volumetric / graduated / standard flask [1]

(ii) 0.0064 [1]

(iii) 1.20 g / 100 cm^3 solution [1]

(iv) 12.0 g / 100 cm^3 solution [1]

(b) (i) The catalyst is in a different physical state to the reactants. [1]

(ii) Bonds broken
2 H-H → 872 1 C-O → 360
1 C-H → 412 1 O-H → 463
1 C=O → 743

Total +2850 kJ (1)

Bonds made
3 C-H → 1236
1 C-O → 360
3 O-H → 1389

Total -2985 kJ (1)

$\Delta H = 2850 - 2985 = -135 \text{ kJ mol}^{-1}$ (1) [3]

(c) Relative molecular mass is a relative quantity (based on $^1/_{12}$th of the ^{12}C atom as one unit). [1]

(d) (i) The rate of the forward reaction is equal to the rate of the backward reaction. [1]

(ii) C_2H_4O [1]

Total [12]

10.

(a) Weighing bottle would not have been washed / difficult to dissolve solid in volumetric flask / final volume would not necessarily be 250 cm^3 [1]

(b) Pipette [1]

(c) To show the end point / when to stop adding acid / when it's neutralised [1]

(d) So that a certain volume of acid can be added quickly before adding drop by drop / to save time before doing accurate titrations / to give a rough idea of the end point [1]

(e) To obtain a more reliable value [1]

(f) (i) Moles = 0.730/36.5 = 0.0200 (1)

Concentration = 0.02/0.1 = 0.200 mol dm^{-3} (1) [2]

(ii) Moles = 0.2 x 0.0238 = 0.00476 [1]

(iii) 0.00476 [1]

(iv) 0.00476 x 10 = 0.0476 [1]

(v) M_r = 1.14/0.0476 = 23.95 [1]

(vi) Lithium [1]

- mark consequentially throughout (f)

Total [12]

11.

(a) Filtration [1]

(b) $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ [1]

(c) (i) Carbon O.S. at start = +3; Carbon O. S. at end = +4 [1]

(ii) $2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$ [1]

(d) Colour change of manganate(VII) is used to indicate the change [1]

(e) Volume of manganate(VII) = 27.92 cm^3 (1)

Moles manganate = 27.92 × 0.020 / 1000 = 5.584×10^{-4} mol (1)

Moles oxalate = $5.584 \times 10^{-4} \times 5/2 = 1.396 \times 10^{-3}$ mol (1)

Concentration = $1.396 \times 10^{-3} / 25 \times 10^{-3} = 0.0558$ mol dm^{-3} (1) [4]

(f) (i) $K_a = \frac{[H^+][HCOO^-]}{[HCOOH]}$ [1]

(ii) $[H^+]^2 = K_a \times [HCOOH] = 1.8 \times 10^{-4} \times 0.2 = 0.36 \times 10^{-4}$ (1)

$[H^+] = 6.0 \times 10^{-3}$ mol dm^{-3} (1)

pH = –log $[H^+]$ = 2.22 (1) [3]

(iii) A buffer keeps the pH almost constant when **small amounts** of acid or base are added (1)

$HCOOH \rightleftharpoons HCOO^- + H^+$ (1)

Adding acid shifts the equilibrium to the left which removes H^+ /
Adding base removes H^+ shifts equilibrium to right which replaces H^+ (1)
OR answer in terms of H^+ reacting with methanoate from
sodium methanoate when acid added (1) and methanoic acid replacing H^+
when base removes H^+ (1)

MAX 3 [3]

QWC Selection of a form and style of writing appropriate to purpose and to complexity of subject matter [1]

(g) (i) Orange to green [1]

(ii) CrO_4^{2-} (1) Yellow (1) [2]

Total [20]