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Mark Scheme (Results)

Summer 2016

Pearson Edexcel GCE
in Chemistry (6CH04) Paper 01
General Principles of Chemistry I

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Section A (multiple choice)

Question Number	Correct Answer	Reject	Mark
1	D		**(1)**

Question Number	Correct Answer	Reject	Mark
2	D		**(1)**

Question Number	Correct Answer	Reject	Mark
3	D		**(1)**

Question Number	Correct Answer	Reject	Mark
4(a)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
4(b)	A		**(1)**

Question Number	Correct Answer	Reject	Mark
5(a)	D		**(1)**

Question Number	Correct Answer	Reject	Mark
5(b)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
5(c)	D		**(1)**

Question Number	Correct Answer	Reject	Mark
5(d)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
5(e)	B		**(1)**

Question Number	Correct Answer	Reject	Mark
6(a)	B		**(1)**

Question Number	Correct Answer	Reject	Mark
6(b)	A		**(1)**

Question Number	Correct Answer	Reject	Mark
7(a)	A		**(1)**

Question Number	Correct Answer	Reject	Mark
7(b)	B		**(1)**

Question Number	Correct Answer	Reject	Mark
8	B		**(1)**

Question Number	Correct Answer	Reject	Mark
9(a)	A		**(1)**

Question Number	Correct Answer	Reject	Mark
9(b)	B		**(1)**

Question Number	Correct Answer	Reject	Mark
10(a)	B		**(1)**

Question Number	Correct Answer	Reject	Mark
10(b)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
11	A		**(1)**

TOTAL FOR SECTION A = 20 MARKS

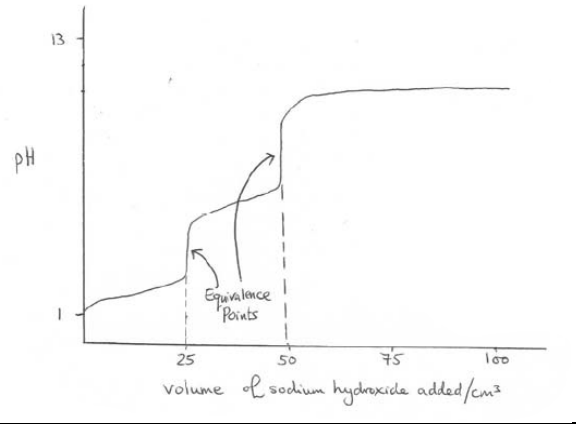
Section B

Question Number	Acceptable Answers	Reject	Mark
12(a)	(K_{a1} =) $\frac{[H_3O^+(aq)]\,[HS^-(aq)]}{[H_2S(aq)]}$ **(1)** (K_{a2} =) $\frac{[H_3O^+(aq)][\,S^{2-}(aq)]}{[HS^-(aq)]}$ Allow $H^+(aq)$ for $H_3O^+(aq)$ Ignore missing / incorrect state symbols **(1)**	$[H_3O^+]^2$ numerator $[H_3O^+]^2$ numerator	**(2)**

Question Number	Acceptable Answers	Reject	Mark
12(b)(i)	(H_2S + H_2O ⇌ H_3O^+ + HS^- Initially 0.100 0 0 At eqm 0.100 x x $K_{a1} = \frac{x^2}{0.100}$) **M1:** $x^2 = 8.91 \times 10^{-9}$ ($mol^2\ dm^{-6}$) **(1)** **M2:** ($x = 9.4393 \times 10^{-5}$) $[HS^-] = 9.44 \times 10^{-5} / 0.0000944$ ($mol\ dm^{-3}$) For M2, answer must be to 3 sf **(1)** Correct answer without working scores (2)		**(2)**

Question Number	Acceptable Answers	Reject	Mark
12(b)(ii)	($[H^+] = (\sqrt{8.91 \times 10^{-9}}$ =) 9.439×10^{-5}($mol\ dm^{-3}$)) pH = ($-\log 9.439 \times 10^{-5}$) = 4.0251/4.025 /4.03/4.0 TE on answer to (b)(i) provided pH <7	 4/4.02	**(1)**

Question Number	Acceptable Answers	Reject	Mark
***12(b)(iii)**	**Any THREE from:** **Assumption 1** $[H_2S]_{equilibrium} = [H_2S]_{initial}$ OR The dissociation of H_2S is negligible OR 0.0000944 is **very** small compared to the initial concentration of H_2S/ 0.100 (hence a valid assumption) **Assumption 2** $[H_3O^+] = [HS^-]$ / $[H^+] = [HS^-]$ OR Ignore any H^+ from (the dissociation of) water / H^+ only from H_2S **Assumption 3** Ignored ionization of HS^- / HS^- doesn't (significantly) dissociate further OR K_{a2} very much smaller than K_{a1} **Assumption 4** Measurements at 298 K / standard **temperature** IGNORE References to the concentration of water References **just** to "standard conditions"		**(3)**

Question Number	Acceptable Answers	Reject	Mark
12(c)(i)	**M1:** General shape of an acid-base curve with the pH increasing and either one or two steep / vertical sections shown **NOTE** Penalise a pH range for a single vertical with a range of eight or more pH units (as this is the typical range for a strong monobasic acid with a strong base titration curve) **(1)** **M2:** Vertical / steep section at 25 cm^3 **(1)** **M3:** Vertical / steep section at 50 cm^3 **(1)** **M4:** Either equivalence point labelled anywhere on vertical section or x-axis **(1)** **M5:** Initial pH = 1.5 **and** a **recognisable** 'plateau' in the pH range of 12 to 13 **(1)** 		**(5)**

Question Number	Acceptable Answers	Reject	Mark
12(c)(ii)	The **pH** when 12.5 cm^3 of NaOH has been added OR the **pH** at "half-equivalence" (for the first equivalence point) **ALLOW** "**pH** at half neutralisation" Allow TE from an incorrect graph		**(1)**

TOTAL FOR QUESTION 12 = 14 MARKS

Question Number	Acceptable Answers	Reject	Mark
13(a)(i)	Ammonia / barium chloride is toxic OR Ammonia / barium chloride is poisonous OR Barium hydroxide is corrosive / caustic OR Ammonia (solution) is corrosive OR Ammonium chloride is harmful / **eye**-irritant ALLOW Barium hydroxide is toxic / poisonous **IGNORE** Use of fume cupboard / gloves, etc	References to just 'barium' Ammonium chloride "is toxic"	**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(a)(ii)	$\Sigma S^{\ominus}_{(products)}$ = ((2 x 192) + (10 x 70) + 124 =) (+)1208 (J mol^{-1} K^{-1}) **(1)** $\Sigma S^{\ominus}_{(reactants)}$ = ((2 x 95) + 427 =) (+)617 (J mol^{-1} K^{-1}) **(1)** $\Delta S^{\ominus}_{system}$ = (1208 – 617 =) +591 J mol^{-1} K^{-1} Allow units in any order **(1)** Correct answer without working scores 3		**(3)**

Question Number	Acceptable Answers	Reject	Mark
***13(a)(iii)**	(Positive value as expected because) 3 moles → 13 moles / more moles of products (than reactants) Allow 'molecules' for moles If numbers (of compounds) are stated, then these must be 3 and 13 **COMMENT:** Ignore any type of particle(s) mentioned **(1)** (Two) solids → a gas / a liquid (+ 1 solid) OR "No gaseous reactants, but gaseous products (formed)" **(1)**	**(0)** **Overall if** $\Delta S^{\ominus}_{system}$ **negative or entropy decrease**	**(2)**

Question Number	Acceptable Answers	Reject	Mark
13(b)	$\Delta S^{\ominus}_{surroundings} = (-\Delta H \div T) = -\frac{162\,000 \text{ J mol}^{-1}}{298 \text{ K}}$ **(1)** $= -543.6241611/-544 \text{ J mol}^{-1} \text{ K}^{-1}$ Allow −0.544 **kJ** $\text{mol}^{-1} \text{ K}^{-1}$ **(1)** Correct answer without working scores 2 IGNORE sf except 1 sf	−543 543	**(2)**

Question Number	Acceptable Answers	Reject	Mark
13(c)	$\Delta S^{\ominus}_{total} = \Delta S^{\ominus}_{system} + \Delta S^{\ominus}_{surroundings}$ $\Delta S^{\ominus}_{total}$ = ans (a)(ii) + ans (b) $= +591 - 544 = +47 \text{ J mol}^{-1} \text{ K}^{-1}$ TE on answers from (a)(ii) and (b)		**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(d)	**M1:** $\Delta S^{\ominus}_{\text{surroundings}}$ becomes less negative / more positive smaller in MAGNITUDE (because you are dividing $-\Delta H$ by a larger T) IGNORE **Just** "smaller" / **just** "decreases" / **just** "bigger" / **just** "greater" **(1)** **M2:** $\Delta S^{\ominus}_{\text{system}}$ / ΔH are not (significantly) affected by a change in temperature **(1)** **M3:** (So) $\Delta S^{\ominus}_{\text{total}}$ increases ALLOW a TE for M3 $\Delta S^{\ominus}_{\text{total}}$ decreases, **only if** incorrect M1 (i.e. $\Delta S^{\ominus}_{\text{surroundings}}$ becomes "less positive") **(1)** Mark M1, M2 and M3 in any order within candidate's answer		**(3)**

Question Number	Acceptable Answers	Reject	Mark
13(e)(i)	($K = e^{(-44/8.31)}$=) 0.005017/ 5.017 x 10^{-3} Ignore any units Allow any sf except 1 sf		**(1)**

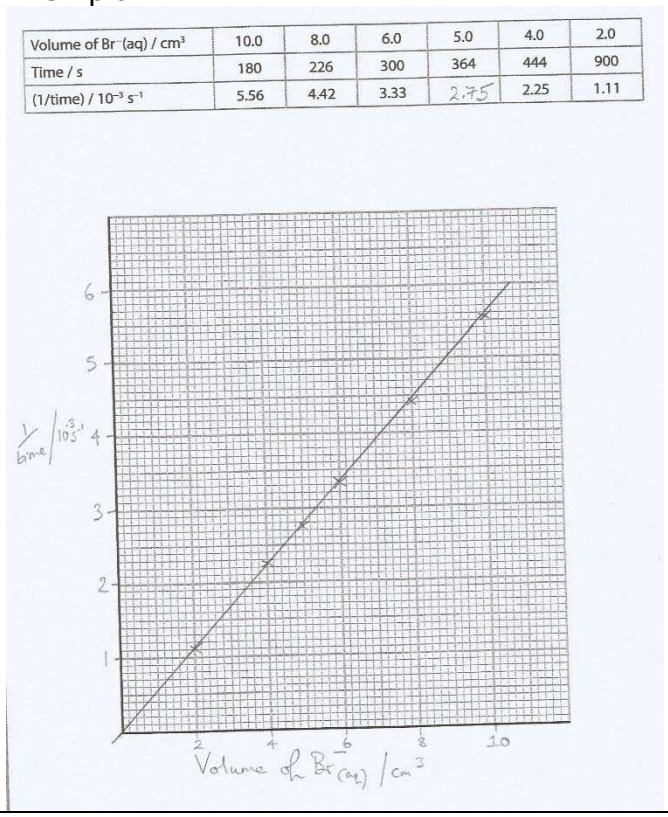
Question Number	Acceptable Answers	Reject	Mark
13(e)(ii)	Barium hydroxide will not be (very) soluble / will be sparingly soluble **and** *K* value suggests that the equilibrium lies to the left-hand side / reactants **OR** ($1x10^{-10}$<) K <1 so reactants predominant No TE on incorrect large value in (e)(i)	Just '*K* is small'	**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(e)(iii)	**M1:** Hydroxides get more soluble as you descend Group 2 **(1)** **M2:** $\Delta S^{\ominus}_{total}$ gets less negative / more positive as you go from $Ca(OH)_2$ to $Ba(OH)_2$ IGNORE **Just** "smaller" / **just** "decreases" / **just** "bigger" / **just** "greater" **(1)** ALLOW Reverse argument No TE on calculated value "more negative" for $Ba(OH)_2$ Mark M1 and M2 independently		**(2)**

TOTAL FOR QUESTION 13 = 16 MARKS

Question Number	Acceptable Answers	Reject	Mark
14(a)	So that the phenol is used up / methyl orange is bleached before the rate changes (significantly) OR So that the phenol is used up / methyl orange is bleached during the initial rate period OR So that the concentration of bromide/bromate/reactants does not fall significantly before all the phenol is used up / the methyl orange is bleached OR Within this region/period/time the average rate of reaction approximates to the initial rate	bromine	**(1)**

Question Number	Acceptable Answers	Reject	Mark
14(b)(i)	So that only the **concentration** of bromide ions varies (significantly) during the course of the reaction / so that the **concentration** of the bromide ions is the limiting factor / so that the **concentration** of bromide ions is the only variable ALLOW So their **concentrations** / the BrO_3^- and H^+ **concentrations** do not change OR So their **concentrations** / the BrO_3^- and H^+ **concentrations** are not the limiting factor		**(1)**

Question Number	Acceptable Answers	Reject	Mark
14(b)(ii)	**M1:** **Completed table** 2.75 **(1)** **M2:** Axes correct with sensible scales so at least half of the graph paper on both axes is covered **(1)** **M3:** Axes labels fully correct, with units **(1)** **M4:** All points plotted correctly (allow ± 1 small square) and straight line drawn **through (0,0)** and through all appropriate points **(1)** Exemplar:  		**(4)**

Volume of Br^-(aq) / cm^3	10.0	8.0	6.0	5.0	4.0	2.0
Time / s	180	226	300	364	444	900
(1/time) / 10^{-3} s^{-1}	5.56	4.42	3.33	2.75	2.25	1.11

Question Number	Acceptable Answers	Reject	Mark
14(b)(iii)	**M1:** First order This mark is independent of the graph drawn **(1)** **M2:** Because the graph is a straight line (through the origin) OR rate is proportional to $[Br^-]$ / rate is proportional to volume of Br^- OR As concentration / volume increases by (factor of) 2, rate increases by 2 (or any other numbers, including 'x') OR Rate increases linearly (with concentration) ALLOW Gradient of line is constant **(1)** **M2** can only be awarded if **M1** correct		**(2)**

Question Number	Acceptable Answers	Reject	Mark
14(b)(iv)	Rate = $k\,[Br^-][BrO_3^-][H^+]^2$ ALLOW 'r =' instead of "rate =" Allow TE on their order wrt Br^- from (b)(iii) **(1)** $dm^9\ mol^{-3}\ s^{-1}$ Allow the units in any order Allow TE for M2 on candidate's stated rate equation **(1)** e.g. if rate = $k\,[BrO_3^-][H^+]$ then TE on units for $dm^6\ mol^{-2}\ s^{-1}$		**(2)**

Question Number	Acceptable Answers	Reject	Mark
14(c)(i)	They are spectator ions OR They are unchanged (on both sides of the equation) OR They do not take part in the reaction / they do not play any part in the reaction ALLOW "They cancel out"		**(1)**

Question Number	Acceptable Answers	Reject	Mark
14(c)(ii)	Blue-black colour appears / turns blue-black ALLOW blue or black / shades of blue or black **IGNORE** Any INITIAL colour Any reference to precipitate / solid	Black from blue Purple Bluer Blacker	**(1)**

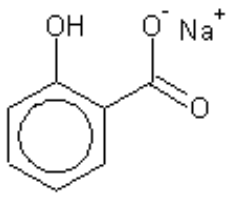
Question Number	Acceptable Answers	Reject	Mark
14 (d)(i)	Measure the time taken (for the blue-black colour to appear) and temperature		**(1)**

Question Number	Acceptable Answers	Reject	Mark
14(d)(ii)	**M1** Temperature converted to kelvin OR K^{-1} given as units on the *x*-axis of the graph **(1)** **M2** The vertical axis should be ln rate / ln 1/t **Note** ALLOW ln *k* for this mark **(1)** **M3** The horizontal axis should be 1/T **(1)** **M4** **Straight** line (with a negative gradient) OR Can be shown by candidate in a sketch graph of a **straight** line with a negative gradient **(1)** **M5** Any mention of **gradient** (of the line) **(1)** **M6** Rearranges expression so: E_a = **−**gradient x *R* OR 'Multiply gradient by –R' Negative sign MUST be shown or mentioned specifically **(1)** **NOTE:** Plot "ln rate **against** 1/T" scores both M2 and M3 If axes clearly the wrong way round max (4) – namely only marks M1, M4, M5 and M6 are possible	1/**T** 1/**t**	**(6)**

(TOTAL FOR QUESTION 14 =19 MARKS)

TOTAL FOR SECTION B = 49 MARKS

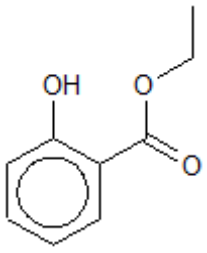
Section C

Question Number	Acceptable Answers	Reject	Mark
15(a)(i)	 → + CH_3OH ALLOW COO^-Na^+ for carboxylate group Skeletal drawing —OH for methanol Ignore omission of charges	O—$Na^{(+)}$	**(1)**

Question Number	Acceptable Answers	Reject	Mark
15(a)(ii)	No more precipitate formed / No more solid formed / solution turns universal indicator paper red / litmus red / pH meter reading below 7 IGNORE Tests involving gas formation with metals or carbonates "No further reaction" **Just** 'use indicator/pH meter'	Precipitate "**disappears"** effervescence fizzing bubbles	**(1)**

Question Number	Acceptable Answers	Reject	Mark
15(b)	(Sparingly soluble because of) the London forces between **the rings** / between **the molecules** ALLOW van der Waals' forces / induced dipole / instantaneous dipole-induced dipole / temporary dipoles for London forces Ignore references to **permanent** dipoles **(1)** Hydrogen bonds between salicylic acid **and water** (which increases solubility) **(1)** IGNORE Any mention of "hydrophobic"		**(2)**

Question Number	Acceptable Answers	Reject	Mark
15(c)	Any three from (Acid hydrolysis) The acid is a catalyst (not a reagent) OR The reaction is reversible / is an equilibrium reaction / does not go to completion / produces lower yield **IGNORE** References to number of steps (needed to produce product) OR Produces the (carboxylic) acid (not its salt) OR The H^+ is an electrophile (and the OH^- nucleophile) ALLOW reverse arguments		**(3)**

Question Number	Acceptable Answers	Reject	Mark
15(d)(i)	**A** PCl_5/$SOCl_2$/ PCl_3 **(1)** **B** $LiAlH_4$ **(1)** ALLOW names for A and/or B **C**  Allow $COOC_2H_5$ / $COOCH_2CH_3$ for ester group **(1)**	HCl $NaBH_4$	**(3)**

Question Number	Acceptable Answers	Reject	Mark
15(d)(ii)	Any two from four differences: Compound D produces hydrogen chloride **and** not water OR Compound D reacts irreversibly not reversibly / goes to completion / produces higher yield OR Compound D reacts faster / more vigorously / reacts with alcohols without the need for a catalyst or H^+ ALLOW Compound D reacts more exothermically OR Compound D produces only one liquid / produces only one solid product (and so no further separation is needed) **IGNORE** References to heating reagents	 HCl**(aq)**	**(2)**

Question Number	Acceptable Answers	Reject	Mark
***15(e)**	**M1** Three (proton / hydrogen) environments **NOTE**: This must be stated. **(1)** **M2** One singlet **and** one triplet **and** one quartet OR these shown on diagram **(1)** **M3** Splitting is due to (n+1) rule / number of adjacent hydrogen atoms **NOTE**: This must be clearly stated **at least once** in candidate's answer and not contradicted by a wrong splitting pattern **(1)** **M4** (Area ratios of peaks) 3:2:1 stated/or relative order **and** consistent with CH_3:CH_2:OH Can be shown on annotated (displayed) formula of ethanol ALLOW reference to height ratios **(1)** **M5** (Chemical shift values, δ, in ppm) Singlet = 2.0 - 4.0, Triplet = 0.1 - 1.9, Quartet = 3.0 - 4.2 OR shown on diagram Allow any single value, or range of values, within these ranges **(1)**	'adjacent **carbons**'	**(5)**

Question Number	Acceptable Answers	Reject	Mark
15(f)	Because it has **12** protons/ hydrogen atoms in the same environment/are equivalent		**(1)**

Question Number	Acceptable Answers	Reject	Mark
15(g)	Radio waves Ignore electromagnetic radiation	In combination with infrared/microwaves/uv	**(1)**

Question Number	Acceptable Answers	Reject	Mark
15(h)	**Any two from three:** **Salicylic acid** (has O-H at) **3300-2500** (cm^{-1}) Ignore the phenolic OH between 3750-3200 (cm^{-1}) for salicylic acid OR Compound **D** (has C=O at) **1795** (cm^{-1}) **and** **1700-1680** (cm^{-1}) for **salicylic acid** **ALLOW** **1725-1700** (cm^{-1}) for **salicylic acid** OR Compound **D** (has C-Cl at) **800-600** (cm^{-1})	1740-1720 (cm^{-1})	**(2)**

TOTAL FOR SECTION C (QUESTION 15) = 21 MARKS

TOTAL FOR PAPER = 90 MARKS

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