AN ROINN OIDEACHAIS AGUS EOLAÍOCHTA | DEPARTMENT OF EDUCATION AND SCIENCE

Scéimeanna Marcála — *Scrúduithe Ardteistiméireachta, 2001*

Ceimic — *Ardleibhéal*

Marking Scheme — *Leaving Certificate Examination, 2001*

Chemistry — *Higher Level*

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Leaving Certificate Examination 2001

Chemistry – Higher level

Marking Scheme

Introduction

In considering the marking scheme the following should be noted.

1. In many cases only key phrases are given which contain the information and ideas that must appear in the candidate's answer in order to merit the assigned marks

2. The descriptions, methods and definitions in the scheme are not exhaustive and alternative valid answers are acceptable.

3. The detail required in any answer is determined by the context and the manner in which the question is asked, and by the number of marks assigned to the answer in the examination paper, and in any instance, therefore, may vary from year to year.

4. The bold text indicates the essential points required in the candidate's answer. Words, expressions or statements separated by a solidus (/) are alternatives which are equally acceptable. A word or phrase in bold, given in brackets, is an acceptable alternative to the preceding word or phrase.

5. Names and formulae of elements and compounds are equally acceptable except in cases where either the name or the formula is specifically asked for in the question.

6. There is a deduction of one mark for each arithmetical slip made by a candidate in a calculation.

Outline marking scheme

1. **Answer *eleven* of the following items (a), (b), (c) etc.**
(a) (i) 3, (ii) 3; (b) 3, 3; (c) 6 or 2 x 3; (d) 3, 3; (e) 3 ,3 ; (f) 3, 3; (g) 3, 3; (h) (i) 3, (ii) 3; (i) 6; (j) 3, 3; (k) 3, 3; (l) 6 or 3; (m) 2 x 3; (n) 2 x 3; (o) 6 or 2 x 3.
Note: one additional mark is awarded to each of the first four items for which the highest marks are obtained. This gives a maximum mark of 70 for the question as a whole.

2. (i) Weigh 3, Make up 3 x 3; (ii) Indicator 3, Colour change 3; (iii) Wash 2 x 3, Use 3; (iv) State 6, 3, 3; (v) Calculate 9 or 6, 3 ; (vi) Value of x 12 or 4 x 3; (vii) 6.

3. (i) Identify X 3, Y 3, Equation 6; (ii) Why 6; (iii) Why 3, Remove 3; (iv) Bromine 3, Conclusion 3, Product 3, 3; (v) $KMnO_4$ 3, Name 3, Use 3; (vi) What 2 x 3, Solid 3; (vii) Isomers 2 x (2 x 3).

4. (i) Which 6; (ii) Explain (a) 2 x 3, (b) 3, (c) 3; (iii) Identify 3, Use 3, Equation 3, 3; (iv) Define 2 x 3, Which 3, Reasons 2 x 3; (v) Write 3, 3, Explain 3 x 3; (vi) Why 6 or 3.

5. Define (i) 2 x 3, (ii) 2 x 3, (iii) 2 x 3; (i) Explain 6 or 3; (ii) Use 12 or 4 x 3; (iii) Outline 5 x 3; (iv) ΔH_n 6 or 2 x 3, 6 or 2 x 3, Reason 3.

6. (i) Give 3, 3, 3, 3, 3; (ii) Alkane 3, Other 3; (iii) Aromatic 3, 3, Write (a) 3, (b) 3; (iv) Which 3, Acid 3, 3; (v) Reduce 6, How 2 x 3 or 6; (vi) Polymers 3, 3, Units 6 or 3.

7. (a) State 6; (i) Identify X 3, Y 3; (ii) Anode 2 x 3, Cathode 2 x 3; (iii) Current 9 or 3 x 3 or 6,3; Volume 3.
(b) (i) Why 6; (ii) Explain 3, What 3; (iii) Other 3, Equation 3, 3; (iv) Identify A 3, B 3, Why 3.

8. Explain (a) 3, (b) 3, (c) 6, (d) 6, Agent 3, What (a) 3, (b) 3; (i) Pairs 3, 3; (ii) K_a 6; (iii) Is 3, Reason 3; (iv) pH 9 or 3 x 3; (v) % 12 or 4 x 3.

9. State (a) 2 x 3, (b) 2 x 3; (i) K_c 6, Calculate 15 or 5 x 3; (ii) USE 9 or 3 x 3; (iii) K_p 6, Calculate 12 or 4 x 3; (iv) Would 3, Explain 3.

10. (a) (i) What 2 x 3; (ii) Outline 4 x 3; (iii) Equation 3, 3; (iv) Mass 9 or 3 x 3.

    (b) (i) Moles 6 or 2 x 3, 6 or 2 x 3; (ii) Show 3 x 3; (iii) Product 3, What 3 x 3.

    (c) Classify 3, 3, 3, 3; (i) Write 2 x 3, (ii) Write 3; (iii) Write 2 x 3, 2 x 3.

    (d) Define 2 x 3; (i) Show 3, 3, 3, Balance 9 or 3 x 3; (ii) Explain 6, 3

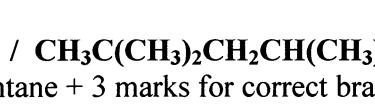
QUESTION ONE

(a) (i) **34** (3) (ii) **45** (3)

(b) **molecular** (3) **Van der Waals' / London / Dispersion** (3)

(c) **56** (6) $1.5 \times 10^{21} \div 6 \times 10^{23} =$ **0.0025** (3) x 22400 = **56** (3) [Answer = 0.056 : – 1]

(d) $\mathbf{Br_2 + 2KI = 2KBr + I_2}$ / $\mathbf{Br_2 + 2I^- = 2Br^- + I_2}$ / **÷2** (Formulae 3, Balancing 3)

(e) $\mathbf{(CH_3)_3CCH_2CH(CH_3)_2}$ / $\mathbf{CH_3C(CH_3)_2CH_2CH(CH_3)CH_3}$ /  (6)
[3 marks for a trimethylpentane + 3 marks for correct branching]

(f) **linear / straight** (3) **V–shaped / bent** (3) [Accept appropriate diagrams.]

(g) **name** (3) **formula** (3) [calcium sulphate {$CaSO_4$}, magnesium sulphate {$MgSO_4$}, calcium chloride {$CaCl_2$}, magnesium chloride {$MgCl_2$}, magnesium hydroxide {$Mg(OH)_2$}, calcium hydroxide {$Ca(OH)_2$}]

(h) (i) **nothing /no reaction** (3) (ii) **copper / copper colour / red / brown / pink / salmon / liquid (water) / oxide reduced / changing from black / red becoming lighter / hydrogen replaces copper** (3)
[Observation can be deduced from equation.]

(i) Idea of **increased atomic radius / atoms getting bigger / greater bond length / decreased electroneg. difference / decreased pulling power / decrease in polarity / decreased electronegativity / decrease in extra ionic resonance energy / orbital mismatch** of combining orbitals / **extra ionic character** (6)

(j) homogeneous: **catalyst and reactants in same phase (no boundary between catalyst and reactants** (3)
heterogeneous: **catalyst and reactants in different phase (boundary between catalyst and reactants)** (3) [Note: If term *state* is used in place of *phase* in both allow (3) only.]

(k) **strong acid-strong base** (3) **weak acid-strong base** (3)

(l) species having **having odd (unpaired) electron** / stated idea of **formed by homolysis (equal splitting)** of bond (6) [Note: Allow 3 marks for a valid example e.g. chlorine atom or $Cl^{\bullet}$.]

(m) **first** (3) **ionisation** energy (3)

(n) **silver nitrate / silver(I) nitrate / $AgNO_3$** (3) // **white ppt soluble in ammonia (NH_3)** soln (3)

(o) **0.00025 (2.5×10^{-4})** (6) 8 ÷ 1000 = **0.008** (3) ÷ 32 = **0.00025** (3)

QUESTION TWO

(i) WEIGH: **suitable container** (e.g. bottle, clock glass, watch class, beaker, boat, etc.) (3)

MAKE UP: **transfer solution and rinsings (washings) to** volumetric **flask** (3)
bottom of meniscus at mark (3)
inverting / mixing / shaking (3)

(ii) NAME: **indicator** (3) **colour change** (3)

methyl orange	yellow/orange to red/pink
methyl red	yellow to red/pink
methyl yellow	yellow to red/pink
bromophenol blue	purple/violet to yellow
bromocresol green	blue to yellow

(iii) WASH: rinse with deionised **water** (3) // followed by **solution** (3)

USE: **filling above mark with pipette filler** /setting **bottom of meniscus on mark / fill up to mark / any detail of emptying (drainage, tip against side of flask, leaving last drop)** (3)

(iv) STATE: **remove funnel / vertical / jet (below tap) full / no air bubbles / read at eye-level / read at bottom of meniscus / drying (removing droplets from) outside / add dropwise near end-point / rough titration** ANY THREE: (6, 3, 3)

(v) CALC: **0.04** mol dm^{-3} (9) $\frac{\mathbf{25 \times M}}{\mathbf{1}} = \frac{\mathbf{20 \times 0.1}}{\mathbf{2}}$ (6) M = **0.04** (3)

(vi) VALUE: **8 / 8.1 / number between 8 and 8.1** (12)

0.04 M = **4.24** g dm^{-3} / **0.01** mol in 250 cm^3 (Na_2CO_3) (3)
= **1.06** (g Na_2CO_3) / 2.51 x 4 = **10.04** (g dm^{-3} cryst) (3)
2.51 – 1.06 = **1.45** / 10.04 – 4.24 = **5.8** / 106 = **145** (H_2O)(3)
$\frac{145}{18} / \frac{1.06}{1.45} = \frac{106}{18x} / \frac{4.24}{5.8} = \frac{106}{18x}$ = **8.1** (3)

OR

2.51 x 4 = **10.04** (3)
10.04 ÷ 0.04 = **251** (3)
251 – 106 = **145** (3)
$\frac{145}{18}$ = **8.1** (3)

(vii) WHY: Na_2CO_3 is **pure / stable / anhydrous (not hydrated) / no water loss (no efflorescence) / solution of exact concentration can be made/ no need to standardise** by titration / **any opposite point for sodium carbonate crystals** (6)

QUESTION THREE

(i) IDENTIFY: X = **ethanol / ethyl alcohol / C_2H_5OH** (3)
Y = **aluminium oxide / alumina / Al_2O_3** (3)

EQUATION: **$C_2H_5OH = C_2H_4 + H_2O$ /$C_2H_5OH - H_2O = C_2H_4$ / $C_2H_5OH \xrightarrow{-H_2O} C_2H_4$** (6)

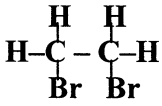
(ii) WHY: idea of **faster absorption / avoids liquid remaining on top of glass wool / enough glass wool can be added to soak up all of liquid / avoids "wetting"** inside of **test tube (dries** inside of **test tube) / keeps ethanol behind glass wool** (6)

(iii) WHY: containing **air** (3)

REMOVE: idea of **preventing suckback** of water (3)

(iv) BROMINE: **decolorising (change to colourless) / becomes pale** (3)

CONCLUSION: evidence for **unsaturation / multiple (double or triple bond) / double bond** in ethene (3)

PRODUCT: **1,2-dibromoethane** (3) STR: **$(CH_2Br)_2$ / CH_2BrCH_2Br /**  (3)

(v) $KMnO_4$: **decolorised (change to colourless) / becomes pale** (3)

NAME: **ethane-1,2-diol / 1,2-ethanediol / ethylene glycol / glycol** (3)

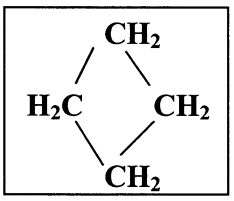
USE: **antifreeze (coolant, preventing ice on aircraft) / making polymers (polyesters,** synthetic **fibres / fabrics) / making named polymer** e.g. terylene [dacron , polyethylene terephthalate (PET)] / **making explosives** (e.g. dynamite) / **making** diethyl **ether (ethoxyethane)** (3)

(vi) WHAT: idea of **breaking (splitting) large (long) molecules (compounds)** (3)
using heat and **a catalyst** (3)

SOLID: **porcelain / porous pot / steel wool / iron / silica-alumina / alumina-silica-platinum / etc.** (3)

(vii) ISOMERS:

$CH_3CH_2CH=CH_2$	**but-1-ene / 1-butene**
$CH_3CH=CHCH_3$	**but-2-ene / 2-butene***
$CH_2=C(CH_3)_2$ / $CH_2=C(CH_3)CH_3$	**2-methylpropene / methylpropene**
See box for structure	**cyclobutane**



For each of any <u>two</u> isomers: **name** (3) **structure** (3)
* Accept *cis*- and *trans*-2-butene as <u>two</u> isomers. For the structure marks, the structures must be clearly shown.

QUESTION FOUR

(i) WHICH: **Helium** (6)

(ii) EXPLAIN: (a) **increased nuclear charge (inc. at. no., positive charge, number of protons)** (3)
which is **effective** / idea of **same inner shells (levels) / same screening (shielding) / electrons going into same outer shell (level)** (3)

(b) idea of **extra shell (level)** of electrons [Accept increased screening as inferring extra shells.] (3)

(c) idea of **no change in effective nuclear charge / change in nuclear charge offset by changed shielding (screening) / difference in electrons in inner (penultimate, second-last shell/level) / electrons going into inner shell (level)** / all **d-block** (3)

(iii) IDENTIFY: **chlorine / Cl / dichlorine / Cl_2** (3)

USE: **water purification / disinfectant / bleach / war / manufacture of HCl (PVC, etc.)** (3)
[Allow for correctly matched use of incorrect element.]

EQUATION: **$AlCl_3 + 3H_2O = Al(OH)_3 + 3HCl$ / $Al_2Cl_6 + 6H_2O = 2Al(OH)_3 + 6HCl$ / $2AlCl_3 + 3H_2O = Al_2O_3 + 6HCl$ / $Al_2Cl_6 + 3H_2O = Al_2O_3 + 6HCl$ / $2AlCl_3 + 6H_2O = Al_2O_3.3H_2O + 6HCl$ / $Al_2Cl_6 + 6H_2O = Al_2O_3.3H_2O + 6HCl$ / $AlCl_3 + H_2O = AlCl_2OH + HCl$ / $Al_2Cl_6 + 2H_2O = 2AlCl_2OH + 2HCl$** (3, 3)
[Allow for correctly matched equation of incorrect compound.]

(iv) DEFINE: relative (measure of) **attraction (pulling power)** (3)
for shared electrons / for electrons in a covalent bond (3)

WHICH: **hydride of nitrogen / ammonia / NH_3** (3)

REASONS: it is **polar** / idea of **electronegativity difference** between N and H / **not pure covalent** (3)
forming hydrogen bonds with water / idea of attraction to water which is polar (which has electronegativity difference / which is not pure covalent) (3)

OR **hydride of phosphorus non-polar** / idea of **no electronegativity difference / not pure covalent** (3)
not forming hydrogen bonds with water / no (weak) attraction to water which is polar (which has electronegativity difference / which is not pure covalent) (3)

(v) WRITE: Cr = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$ / $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$ / [Ar] $3d^5\ 4s^1$ (3)
Cu = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^{10}$ / $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$ / [Ar] $3d^{10}\ 4s^1$ (3)

EXPLAIN: idea of **stability** (3) **of half-full sublevel (subshell) / of $3d^5 4s^1$ / of $3d^5$** for Cr (3)
of full sublevel **(subshell) / of $3d^{10} 4s^1$ / of $3d^{10}$** for Cu (3)

OR: **normal order *4s* before *3d*** (3) exception due to **stability of half-full sublevel (subshell) / of $3d^5 4s^1$ / of $3d^5$** for Cr (3) and of **full** sublevel (subshell) / **of $3d^{10} 4s^1$ / of $3d^{10}$** for Cu (3)

(vi) WHY: transition: **Cr, Cu** can **have incomplete d / Zn has complete d / Cr, Cu have variable valence / Zinc has fixed valence / Cr, Cu have coloured compounds (ions) / Zinc does not have coloured cpds (ions) / Cr, Cu catalysts / Zn not catalyst** (6)

[*If no marks are merited for transition , three marks can be given for d-block:*
d-block: idea of **highest energy electron in d / electrons entering (occupying) d / electrons filling inner d / electrons entering d after s** (3)]

QUESTION FIVE

DEFINE: (i) heat ch. for **1 mole** (3) **formed from elements** (3)
(ii) heat ch. for **1 mole** (3) **burned completely (in excess oxygen, to normal oxides)** (3)
(iii) heat ch. for **1 mole of hydrogen ions (H^+)** (3) **neutralised (reacted with base/OH^-)** (3)
OR:heat ch. for **1 mole of water (H_2O)** (3) **formed by neutralisation (acid-base reaction)** (3)

EXPLAIN: (i) **ethanoic acid cannot be formed** directly **from elements / formation of ethanoic acid is not a combustion reaction** (6)
[Note: they (carbon dioxide and water) can be formed directly from elements / formation reactions for carbon dioxide and water are also combustion reactions (3) only.]

(ii) USE: $\Delta H = -$ **484** kJ mol^{-1} (12) [+ 484 to get 9 marks]

$C + O_2 = CO_2$ $\Delta H = -394$ kJ mol^{-1} ; $H_2 + \frac{1}{2}O_2 = H_2O$ $\Delta H = -286$ kJ mol^{-1} ;
$CH_3COOH + 2O_2 = 2CO_2 + 2H_2O$ $\Delta H = -876$ kJ mol^{-1}

$2C + 2O_2$	**=**	**$2CO_2$**	**–788**	(3)
$2H_2 + O_2$	**=**	**$2H_2O$**	**–572**	(3)
$2CO_2 + 2H_2O$	**=**	**$CH_3COOH + 2O_2$**	**876**	(3)
$2C + 2H_2 + O_2$	**=**	**CH_3COOH**	**–484**	(3)

(iii) OUTLINE: **suitable container** [polystyrene (styrofoam, polythene, plastic, etc.) cup / glass vessel such as beaker / thermos flask / calorimeter / etc.]
of known heat capacity
known **vols & concs of acid & base** / known **vol & conc acid &** known **vol base**
measure initial temperature, mix and note new (highest) **temperature (mix and note rise in temperature)**
calculate heat produced / mcθ / mcΔθ
calc for 1 mole H^+ (1 mole H_2O) / calc heat of neutralisation ANY FIVE: (5 x 3)

(iv) ΔH_n: ethanoic acid: (–) **55.8** kJ mol^{-1} (6) sulphuric acid: (–) **57.2** kJ mol^{-1} (6)

CH_3COOH: $\frac{1}{20} / \frac{1 \times 50}{1000}$ = 0.05 mol acid ≡ **0.05** mol H^+ [0.05 mol H_2O] (3)
heat of neutralisation of ethanoic acid [2.79 ÷ 0.05] = **55.8** (3)
OR: $\frac{\mathbf{2.79 \times 1000}}{\mathbf{50}}$ (3) = **55.8** (3)

H_2SO_4: $\frac{1}{20} / \frac{1 \times 50}{1000}$ = 0.05 mol acid ≡ **0.1** mol H^+ [0.1 mol H_2O] (3)
heat of neutralisation of sulphuric acid [5.72 ÷ 0.1] = **57.2** (3)
OR: $\frac{\mathbf{5.72 \times 1000}}{\mathbf{50}}$ / = **114.4** (3) kJ for neutralisation of 2 mol H^+ = **57.2** (3)

REASON: sulphuric acid: **strong (dissociated, present as ions, energy not needed to dissociate) /**
ethanoic acid: **weak (undissociated, slightly dissociated, present as molecules, energy needed to dissociate)** (3)

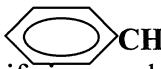
QUESTION SIX

(i) GIVE:

A: butane (3)
B: propanone (3)
C: propenonitrile (3)
D: methyl ethanoate (3)
E: phenylethene (3)

(ii) ALKANE: **A / butane / $CH_3CH_2CH_2CH_3$ / C_4H_{10}** (3)

OTHER: **name / formula** (3) [pentane (C_5H_{12}) – heptadecane ($C_{17}H_{36}$)]

(iii) AROMATIC: **E / phenylethene / styrene / $C_6H_5CH=CH_2$ /**  **$CH=CH_2$ / C_8H_8** (3)
common name: **styrene** [need not be repeated if given under *aromatic*] (3)

WRITE: (a) molecular formula: **C_8H_8 / H_8C_8 / $(CH)_8$** (3)
(b) empirical formula: **CH / HC** (3)

(iv) WHICH: **D / methyl ethanoate / CH_3COOCH_3 / $C_3H_6O_2$** (3)

ACID: name: **propanoic (propionic)** acid (3) structure: **CH_3CH_2COOH / C_2H_5COOH** (3)

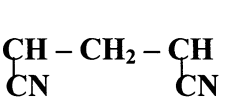
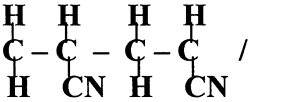
(v) REDUCE: **B / propanone / acetone / CH_3COCH_3 / C_3H_6O** (6)

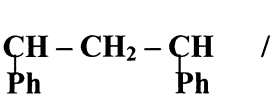
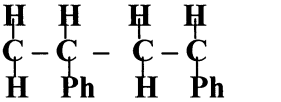
HOW: heat with **hydrogen (H_2) / hydrogenation** (3)
and **nickel (Ni) / palladium (Pd) / platinum (Pt)** catalyst (3)

OR: **lithium aluminium hydride ($LiAlH_4$, lithium tetrahydoaluminate) / sodium borohydride ($NaBH_4$, sodium tetrahydroborate)** (6)

(vi) POLYMERS: **C / propenonitrile / acrylonotrile / cyano acrylate / vinyl cyanide / $CH_2=CHC\equiv N$ / $CH_2=CHCN$ / C_3H_3N** (3)

E / phenylethene / styrene /  **$CH=CH_2$ / $C_6H_5CH=CH_2$ / C_8H_8** (3)

UNITS: **$CH_2CH(CN)CH_2CH(CN)$** /  / 
[*accept adjacent CNs*]

$CH_2CH(Ph)CH_2CH(Ph)$ /  /  (6)
[*accept adjacent Phs*]

[**Ph** = the phenyl radical which may be represented by C_6H_5 or the benzene ring.]
[Note; If more than two full repeating units given allow (3) only]

QUESTION SEVEN

(a) STATE: **mass (amount of chemical change) proportional to charge (quantity of electricity) / $m \propto Q$ / $m = kQ$ / $\frac{m}{Q} = k$** (6)

(i) IDENTIFY: X = **hydrogen / dihydrogen / H_2** (3) Y = **oxygen / dioxygen / O_2** (3)

(ii) ANODE: **$H_2O = \frac{1}{2}O_2 + 2H^+ + 2e^-$** / [accept **$2OH^- = \frac{1}{2}O_2 + H_2O + 2e^-$**]/– **$2e^-$ on LHS / x 2** (3, 3)

CATHODE: **$H_2O + e^- = \frac{1}{2}H_2 + OH^-$** / [accept **$H^+ + e^- = \frac{1}{2}H_2$**] / **x 2** (3, 3)

(iii) CURRENT: **1.875 / 1.88 / 1.9** A (9)

$\frac{45}{24000}$ = **1.875×10^{-3}** mol O_2 (3) x 4 x 96500 = **723.75** (3) $\frac{723.75}{386}$ = **1.875** (3)

OR

$\frac{\text{1 x current x 386}}{\text{2 x 96500}}$ = **0.00375** / $\frac{\text{16 x current x 386}}{\text{2 x 96500}}$ = **0.06** (6)

=> current = **1.875 / 1.88 / 1.9** A (3)

OR

1 F / 96500 C ⟶ 0.5 mol O^{2-} / 0.25 mol O_2 / 8 g / 6000 cm^3 [or multiples] (3)

45 cm^3 / 0.001875 mol O_2 / 0.00375 mol O^{2-} / 0.06 g ⟶ 723.75 C (3)

386 x current = 723.75 => current = **1.875 / 1.88 / 1.9** A (3)

VOLUME: **90** cm^3 (3) 45 x 2 = **90** (3)

(b) (i) WHY: idea of **reactive / high in series / stable (unreactive, hard to reduce) compounds (ions)** (6)

(ii) EXPLAIN: adding of **calcium chloride ($CaCl_2$)** / idea of being a **mixture** (3)

WHAT: idea of **lower cost (less energy, less electricity) / easier to maintain temperature / well below boiling point** of sodium / **avoids vaporisation** of sodium (3)

(iii) OTHER: **chlorine / dichlorine / Cl_2** (3)

EQUATION: **$Cl^- = \frac{1}{2}Cl_2 + e^-$** / **$-e^-$ on LHS / x 2** (3, 3)

(iv) IDENTIFY: A = **carbon (graphite) / C** (3) B = **iron / steel / Fe / copper / Cu** (3)

WHY: idea of it (B, iron, steel, Fe) **reacting with chlorine** (3)

QUESTION EIGHT

EXPLAIN: (a) idea of **coagulation (aggregation, clumping, joining) of particles / removal of suspended solids by the addition of** something (3)

(b) pH = **$-\log [H^+]$ / $\log {}^1/_{[H^+]}$ / negative log of hydrogen (hydronium) ion concentration.** [Note: H_3O^+ may be used in place of H^+ here and in all other parts of the question except for (d) below (definition of conjugate pair))] (3)

(c) K_a = **product of concentrations of ions divided by concentration of molecules (undissociated acid) / $\frac{[H^+][A^-]}{[HA]}$** (6)

[allow 3 marks for **measure of dissociation**]

(d) C.P.= acid & base / two species (substances, compounds, molecules, ions) **differing by a proton (hydrogen ion, H^+)** (6)

AGENT: **name *or* formula : aluminium sulphate / aluminium chloride / aluminium(III) / alum / iron(II) sulphate (ferrous sulphate) / iron(III) sulphate (ferric sulphate) / iron(III) chloride (ferric chloride) / iron(III) / lime / polyelectrolytes** /etc. (3)

WHAT: (a) **name *or* formula : calcium hydroxide (lime) / sodium carbonate / soda ash / sodium hydroxide (caustic soda) / base** (3)

(b) **name *or* formula : sulphuric acid / carbon dioxide / acid** (3)

(i) PAIRS: **$HClO$ and ClO^-** (3) **H_2O and H_3O^+** (3)

(ii) K_a: $\frac{[H_3O^+][ClO^-]}{[HClO]}$ / $\frac{[H^+][ClO^-]}{[HClO]}$ (6)

(iii) IS: **weak** (3) REASON: **low K_a / low dissociation (undissociated) / present as molecules /** idea of **few ions (mainly molecules) / poor proton donor /** has **strong conjugate base** (3)

(iv) pH: **3.9** (9) $\frac{[H^+]^2}{0.5} = 3.7 \times 10^{-8}$ (3) => $[H^+] = 1.36 \times 10^{-4}$ (3) => pH = **3.9** (3)

OR **$pH = -\log \sqrt{K_a.M}$** (3) => **$-\log \sqrt{3.7 \times 10^{-8} \times 0.5}$** (3) => pH = **3.9** (3)

(v) %: **$0.06 / 6 \times 10^{-2}$** (12)

$\frac{[H^+]^2}{0.1 - [H^+]}$ / $\frac{x^2}{0.1 - x}$ / $\frac{[H^+]^2}{0.1}$ / $\frac{x^2}{0.1}$ **$= 3.7 \times 10^{-8}$** (3)

$x^2 + 3.7 \times 10^{-8}x - 3.7 \times 10^{-9} = 0$ / **$[H^+]^2$** or **x^2** = $3.7 \times 10^{-8} \times 0.1$ = **3.7×10^{-9}** (3)

OR: **$[H^+] = \sqrt{K_a.M}$** (3) = **$\sqrt{3.7 \times 10^{-8} \times 0.1}$** (3) OR: **pH = 4.2** (3) **inv. log – 4.2** (3)

$[H^+]$ or **x** = **6×10^{-5}** (3) $\frac{6 \times 10^{-5} \times 100}{0.1}$ = **$0.06 / 6 \times 10^{-2}$** (3)

QUESTION NINE

STATE: (a) reactions (systems) **at equilibrium** (3) **oppose (minimise, adjust to) stress (change)** (3)

(b) **pressure of mixture of gases** (3) **equal to sum of partial pressures / equal to sum of pressures each gas would exert if it alone occupied the space** (3)

(i) K_c: $\dfrac{[PCl_3][Cl_2]}{[PCl_5]}$ (6)

CALC: K_c = **0.036 / 3.6 x 10^{-2}** mol dm^{-3} (15)

16.68 ÷ 208.5 = 0.08 mol PCl_5 0.08 mol PCl_5 ÷ 5 = 0.016 *M* PCl_5
8.25 ÷ 137.5 = 0.06 mol PCl_3 0.06 mol PCl_3 ÷ 5 = 0.012 *M* PCl_3

$PCl_5 \rightleftharpoons$	PCl_3	+ Cl_2	
0.08 mol	0	0	(3)
0.02 mol	**0.06** mol	**0.06** mol	(3)
0.004 *M*	**0.012** *M*	**0.012** *M*	(3)

OR

$PCl_5 \rightleftharpoons$	PCl_3	+ Cl_2	
0.08 mol	0	0	(3)
0.016 *M*	0	0	(3)
0.004 *M*	**0.012** *M*	**0.012** *M*	(3)

$K_c = \dfrac{(0.012)^2}{0.004}$ (3) = **0.036** (3)

(ii) USE: Pressure = **1.4** atm (9)

PV = nRT / ***P* x 5 x 10^{-3} = 0.14 x 8.3 x 600** (3)
P = **139 440** Pa (3)
÷ 1 x 10^5 = **1.4** atm (3)

(iii) K_p: $\dfrac{P_{PCl_3}.P_{Cl_2}}{P_{PCl_5}} \;/\; \dfrac{(P_{PCl_3})(P_{Cl_2})}{P_{PCl_5}}$ (6)

CALC: K_p = **1.8** atm (12)

$PCl_5 \rightleftharpoons PCl_3 + Cl_2$
0.02/0.004 0.06/0.012 0.06/0.012 [Totals = 0.14/0.028]

$\dfrac{0.02}{0.14} / \dfrac{0.004}{0.028}$ x 1.4 $\dfrac{0.06}{0.14} / \dfrac{0.012}{0.028}$ x 1.4 $\dfrac{0.06}{0.14} / \dfrac{0.012}{0.028}$ x 1.4 (3)

0.2 atm **0.6** atm **0.6** atm (3)

$K_p = \dfrac{(0.6)^2}{0.2}$ (3) = **1.8** (3)

(iv) WOULD: **greater** (3) EXPLAIN: idea of forward **reaction endothermic (absorbs heat, lowers temperature)** / idea of **forward shift** in reaction (3)

QUESTION TEN

(a) (i) WHAT: **different physical (structural) forms (modifications)** (3) **of element** or compound (3)

(ii) OUTLINE: **burning (oxidation)** of sulphur **to sulphur dioxide / S + O_2 = SO_2** (3)
oxidation of SO_2 to SO_3 / SO_2 + ½O_2 $\rightleftharpoons$ SO_3 (3)
using vanadium(V) oxide (V_2O_5, platinum, Pt, nitrogen monoxide, NO) catalyst (3)
sulphur trioxide passed into conc H_2SO_4 (SO_3 + H_2SO_4 = $H_2S_2O_7$) and water added ($H_2S_2O_7$ + H_2O = $2H_2SO_4$) / sulphur trioxide reacted with water in a spray of dilute sulphuric acid (3)

(iii) EQUAT: **$2NH_3$ + H_2SO_4 = $(NH_4)_2SO_4$** (3, 3)

(iv) MASS: **236** kg (9)

$\frac{28}{132}$ of % $(NH_4)_2SO_4$ = 5 in fertiliser / **21.2 % of % $(NH_4)_2SO_4$ = 5 in fertiliser** (3)

% $(NH_4)_2SO_4$ = 23.6 / **% $(NH_4)_2SO_4$ = 23.6** (3)

23.6 % of 1 tonne = 236 kg (3)

OR **1 tonne => 50 kg nitrogen** (3) **$50 \times \frac{132}{28}$** / **$50 \times \frac{100}{21.2}$** (3) **= 236 kg** (3)

OR **1 t => 50 kg N_2** (3) =1785.7 mol N_2 ≡ **1785.7 mol $(NH_4)_2SO_4$** (3) $\xrightarrow{\times 132 \div 1000}$ **236** kg (3)

OR **1 t => 50 kg N** (3) = 3571.4 mol N ≡ **1785.7 mol $(NH_4)_2SO_4$** (3) $\xrightarrow{\times 132 \div 1000}$ **236** kg (3)

Question 10 continued.

(b) (i) MOLES: oxygen: **2.5** (6); water: **1** (6)

O_2: $84 \div 22400 =$ **3.75×10^{-3}** (3) $\div 1.5 \times 10^{-3} =$ **2.5** (3)
H_2O: $27 \div 18000 =$ **1.5×10^{-3}** (3) $\div 1.5 \times 10^{-3} =$ **1** (3)

(ii) SHOW:

Method 1:

$C_xH_y + {}^{(4x+y)}/_4O_2 = xCO_2 + {}^{y}/_2H_2O$
1 mol 2.5 mol 1 mol ${}^{y}/_2 = 1$ => **y = 2** (3)

${}^{(4x+2)}/_4$ = **2.5** / **moles CO_2** = 2.5 – 0.5 = **2** (3)

x = **2** (3)

Method 2:

2 mol O_2 → 2 mol CO_2 x 1.5×10^{-3} x 44 = **0.132 g (132 mg) CO_2** (3)

C = 132 mg (0.132 g) x ${}^{12}/_{44}$ **= 36 mg (0.036 g) ÷ 12 = 3 (0.003)**
H = 27 mg (0.027 g) x ${}^{2}/_{18}$ **= 3 mg (0.003 g) ÷ 1 = 3 (0.003)**
=> ratio = 1 : 1 => empirical formula = CH (3)

1.5×10^{-3} mol C_xH_y = 36 mg + 3 mg (0.036 g + 0.003 g) **= 39 mg (0.039 g)**
=> **1 mole** = 26000 mg = **26 g (M_r = 26) => molecular formula = C_2H_2** (3)

Method 3:

C_xH_y + 2½O_2 = 2CO_2 + H_2O (3)

$x = 2, y = 2$ / C_xH_y = C_2H_2 / hydrocarbon = C_2H_2 (3, 3)

Method 4:

C_2H_2 + 2½O_2 = 2CO_2 + H_2O (3)

C_2H_2 ≡ 2½O_2 / C_2H_2 ≡ 2CO_2 (3)
C_2H_2 ≡ H_2O (3)

Method 5:

C_2H_2 + 2½O_2 = 2CO_2 + H_2O (3)

1.5×10^{-3} mol C_2H_2 => **1.5×10^{-3} x 2½ x 22400 = 84** cm^3 (3)
1.5×10^{-3} x 18000 = 27 mg (3)

(iii) PRODUCT: **ethanal / acetaldehyde / CH_3CHO** (3)

WHAT: dilute **sulphuric acid** / dilute **H_2SO_4** (3)
mercury (II) sulphate / mercuric sulphate / $HgSO_4$ (3)
warm / heat / boil / temperature given between 40 and 100 °C (incl) (3)

Question ten continued:

(c) CLASSIFY: Al_2O_3 **amphoteric** (3)
CO **neutral** (3)
MgO **basic** (3)
CO_2 **acidic** (3)

(i) WRITE: **CO_2 + 2NaOH = Na_2CO_3 + H_2O / CO_2 + NaOH = $NaHCO_3$** (3, 3)

(ii) WRITE: **MgO + H_2O = $Mg(OH)_2$** (3)

(iii) WRITE: (a) **Al_2O_3 + 6HCl = $2AlCl_3$ + $3H_2O$ /**
Al_2O_3 + 6HCl = Al_2Cl_6 + $3H_2O$ (3, 3)

(b) **Al_2O_3 + 2NaOH = $2NaAlO_2$ + H_2O /**
Al_2O_3 + 2NaOH = $Na_2Al_2O_4$ + H_2O /
Al_2O_3 + 2NaOH + $3H_2O$ = $2NaAl(OH)_4$ (3, 3)

(d) DEFINE: **charge on atom / element** (3) // **if bonds** assumed **ionic / using rules to assign electrons / assignment of electrons** (3)

(i) SHOW: $H^+ + MnO_4^- + C_2O_4^{2-} = CO_2 + Mn^{2+} + H_2O$
(+7) (+3) (+4) (+2)
correct oxidation numbers for Mn / correct oxidation numbers for C (3)

oxidation:**$C_2O_4^{2-}$ / C(+3) / C(3) / C(III) ⟶ CO_2 / C(+4) / C(4) / C(IV)**
[Note: can be indicated on equation] (3)

reduction:**MnO_4^- / Mn(+7) / Mn(7) / Mn(VII) ⟶ Mn^{2+} / Mn(+2) / Mn(2) / Mn(II)**
[Note: can be indicated on equation] (3)

BALANCE: **$16H^+ + 2MnO_4^- + 5C_2O_4^{2-} = 10CO_2 + 2Mn^{2+} + 8H_2O$** /

$16H^+ = 8H_2O$ (3) **$2MnO_4^- = 2Mn^{2+}$** (3) **$5C_2O_4^{2-} = 10CO_2$** (3)

$8H^+ + MnO_4^- + 2½C_2O_4^{2-} = 5CO_2 + Mn^{2+} + 4H_2O$ (9)

$8H^+ = 4H_2O$ (3) **$MnO_4^- = Mn^{2+}$** (3) **$2½C_2O_4^{2-} = 5CO_2$** (3)

(ii) EXPLAIN: **catalyst produced** by reaction / **autocatalysis** (6)

catalyst is **Mn^{2+} [manganese(II)]** / idea of **more catalyst produced** as more $KMnO_4$ reacted / **no (little) catalyst at start** (3)