Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE 2010

MARKING SCHEME

CHEMISTRY

HIGHER LEVEL

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. Whilst only key words and phrases are indicated in the marking scheme they must be presented in answers in a correct context if full marks are to be awarded.

5. In general names and formulas of elements and compounds are equally acceptable except in cases where either the name or the formula is specifically asked for in the question. However, in some cases where the name is asked for, the formula may be accepted as an alternative.

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

7. Where a candidate has received a modified examination paper under the reasonable accommodations arrangements the marking scheme applied has been modified accordingly.

Outline Marking Scheme

Eight questions to be answered in all. These *must* include at **least two** questions from **Section A**.

Section A
Question 1
(a), (3 + 2); (b), (3), (2 x 3); (c), (3, 3, 3); (d), (2 × 3); (e), (6), (3), (3), (3); (f), (6)

Question 2
(a), (5); (b), (6), (3), (3) ; (c), (2 × 3), (3), (3), (6) (3); (d), (12).

Question 3
(a), (5); (b), (3 × 3); (c), (6); (d), (2 × 3), (3), (3), (6); (e), (6); (f), (3), (3).

Section B
Question 4
Eight **highest scoring items to count.** *One* **additional mark to be added to each of the** *first two items* **for which the highest marks are obtained.**

(a), (6); (b), (2 × 3); (c), (2 × 3); (d), (6); (e), (2 × 3); (f), (2 × 3); (g), (2 × 3); (h), (2 × 3); (i), (2 × 3);
(j), (2 × 3); (k), A (2 × 3), B (6).

Question 5
(a), (2 × 4); (b), (3 × 3); (c), [6 + (3 × 3)]; (d), (2 × 3); (e), (2 × 3), (3), (3).

Question 6
(a), [(2 × 3) + 2]; (b), (3), (2 × 3); (c) (3), (3); (d), (2 × 3), (3 × 3); (e), (9), (3).

Question 7
(a), [(2 × 4) + 3]; (b), (2 × 3), (6); (c), (12); (d), (3), (3); (e) (3), (6).

Question 8
(a), (2 × 4), (2 × 3), (3); (b), (2 × 3), (2 × 3); (c), (3), (6), (3 × 3), (3).

Question 9
(a), (5); (b), (2 × 3); (c), (4 × 3); (d), (6), (2 × 3); (e), (3 × 3); (f), (2 × 3).

Question 10
(a), (2 × 3), (2 × 3), (2 × 3), (3), (4).
(b), (i), [6 + (2 × 3)]; (ii), (2 × 3); (iii), (3) ; (iv), (4).
(c), (i), (4 + 3); (ii), (3); (iii), (3 × 3); (iv), (2 × 3).

Question 11
(a), (i), (4); (ii), (3); (iii), (3), (6); (iv), (3); (v), (3), (3).
(b), (i), (3 + 2); (ii), (3 + 2 or 5 or 3, 2); (2 × 3), (3), (3), (3).
(c) **A:** (i), (2 × 3); (ii), (2 × 3); (iii), (2 × 3); (3), (4)
   B: (i), (4); (ii), (3 × 3); (iii), (2 × 3); (iv), (3), (3).

SECTION A

QUESTION 1

(a) NAME: **Ethylenediamine // tetraacetic acid**   (3 + 2)
or
1,2-**bis[bis(carboxymethyl)amino] // ethane**.   (3 + 2)

(b) NAME: **Eriochrome** Black T / **Solochrome** Black T   (3)

COLOURS: Wine **red //**
To blue   (2 × 3)

(c) PURPOSE: **To stabilise the pH** of a solution **/ resist changes in pH**   (3)

BUFFER: **pH 10 / Ammonia-ammonium chloride (other suitable buffer)**   (3)

PROBLEM: **Poor (inaccurate) end point / edta complexing with other ions /
incomplete complexing** with calcium and magnesium ions   (3)

(d) EXPLAIN: **Swirl** to mix **// allow time** after addition from burette for reaction **//
Wash down sides with deionised water // On white surface**   ANY TWO: (2 × 3)

(e) (i): **1.84×10^{-3} / 0.00184** M   (6)

$$\frac{50 \times M}{1} \quad = \quad \frac{9.2 \times 0.01}{1} \quad (3)$$

$$\text{Concentration} = \quad \mathbf{1.84 \times 10^{-3}\,M} \ (3)$$

(ii): **1.84×10^{-1} / 0.184**   (3)
[Answer (i) × 100]

(iii): **184**   (3)
[Answer (ii) × 1000]

REPEAT: **4.8×10^{-4} / 0.00048** M
4.8×10^{-2} / 0.048
48   (3)
[Mathematical "slip" – loses 1 mark; consequential marking applies]

(f) STATE and EXPLAIN: The water is **unsuitable (no) because hardness remaining (ions
present, named ion)** after passing through the deioniser **/**
The deioniser **needs to be replaced (yes) because hardness remaining
(ions present, named ion)** after passing through the deioniser   (6)

[Allow 3 marks for water "unsuitable" or deioniser "needs to be replaced"
if either are offered alone]

QUESTION 2

(a)   WRITE: **Propane-1,2,3-triol / 1,2,3-propanetriol**   (5)
             [Allow 3 marks for " propane" or "numbers" or "triol" or "trihydroxy"]

(b)   WHY: **To bring reaction to completion / to allow time (provide energy) for reaction to complete / to maximise the yield** of soap /
             to heat **without loss of ethanol (vapour, volatile material)**   (6)

      NAME: Base **hydrolysis / saponification** [Accept "substitution"]   (3)

      WHAT: **Solvent**   (3)

(c)   (i):   DESC: **diagram showing flask with condenser in position for distillation //**
                     thermometer (heat with water bath, distill at 78°) and heat source (2×3)
                     [At least one correct label required]
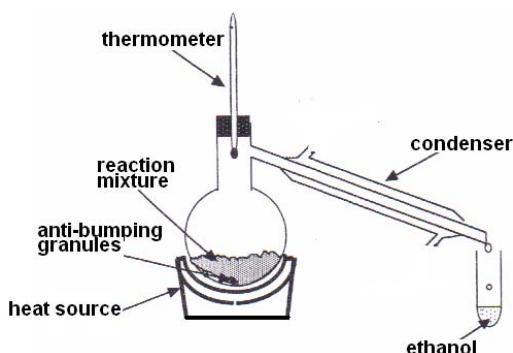
             [No diagram – lose 3 marks]

      (ii)   ISOLATED: reaction mixture **added to brine (saturated sodium chloride solution)**   (3)

                     precipitated soap got by **filtration**   (3)

      (iii)   PURIFIED: **Wash with brine / wash with water**   (6)
                     [Do not accept "Wash with *hot* water"]
             DRIED: **warm place / put in desiccator (dehydrator) / oven / drying tray /**
                     air dry   (3)

(d)   Calculate: **76 – 77%**   (12)

8.9 ÷ 890* = 0.01 mol glyceryl tri. (3)		8.9 ÷ 890* = 0.01 mol glyceryl tri. (3)	
x 3 = 0.03 mol soap (th. yield) (3)		7.0 ÷ 306* = 0.023 mol soap (act. yield) (3)	
0.03 x 306* = 9.18 g soap (th. yield) (3)		0.023 ÷ 3 = 0.0076/0.0077 mol gly. t. reqd. (3)	
$^7/_{9.18}$ x 100 = 76 – 77 % (3)		$^{0.0076/0.0077}/_{0.01}$ = 76 – 77 % (3)	
8.9 ÷ 890* = 0.01 mol glyceryl tri. (3)		7.0 ÷ 306* = 0.023 mol soap (act. yield) (3)	
x 3 = 0.03 mol soap (th. yield) (3)		0.023 ÷ 3 = 0.0076/0.0077 mol gly. t. reqd. (3)	
7.0 ÷ 306* = 0.023 mol soap (act. yield) (3)		0.0076/0.0077 x 890* = 6.82 g gly. t. reqd. (3)	
$^{0.023}/_{0.03}$ x 100 = 76 – 77 % (3)		$^{6.82}/_{8.9}$ x 100 = 76 – 77 % (3)	

[*Addition must be shown for error to be treated as a slip (apply only once); consequential marking applies]

QUESTION 3

(a) IDENTIFY: **Sulfur / S** (5)

(b) DESCRIBE: **Measure (take) 30 cm^3** of the 0.20 M thiosulfate solution **// dilute (make up) to 50 cm^3 //**
using deionised **water** (3 × 3)

(c) WHY: **So that only one variable is changed / to keep the test valid (fair) /**
so as to keep the total volume the same / so as not to change the conc. of another
species present / to keep the same depth / should be only two variables (6)

(d) PLOT: **Correctly labelled // scaled axes** (2 × 3)
All points plotted (3)
Straight line drawn (3)

CONCLUSION: Rate **proportional** to concentration (6)
[Allow 3 marks for "**Linear** relationship"]
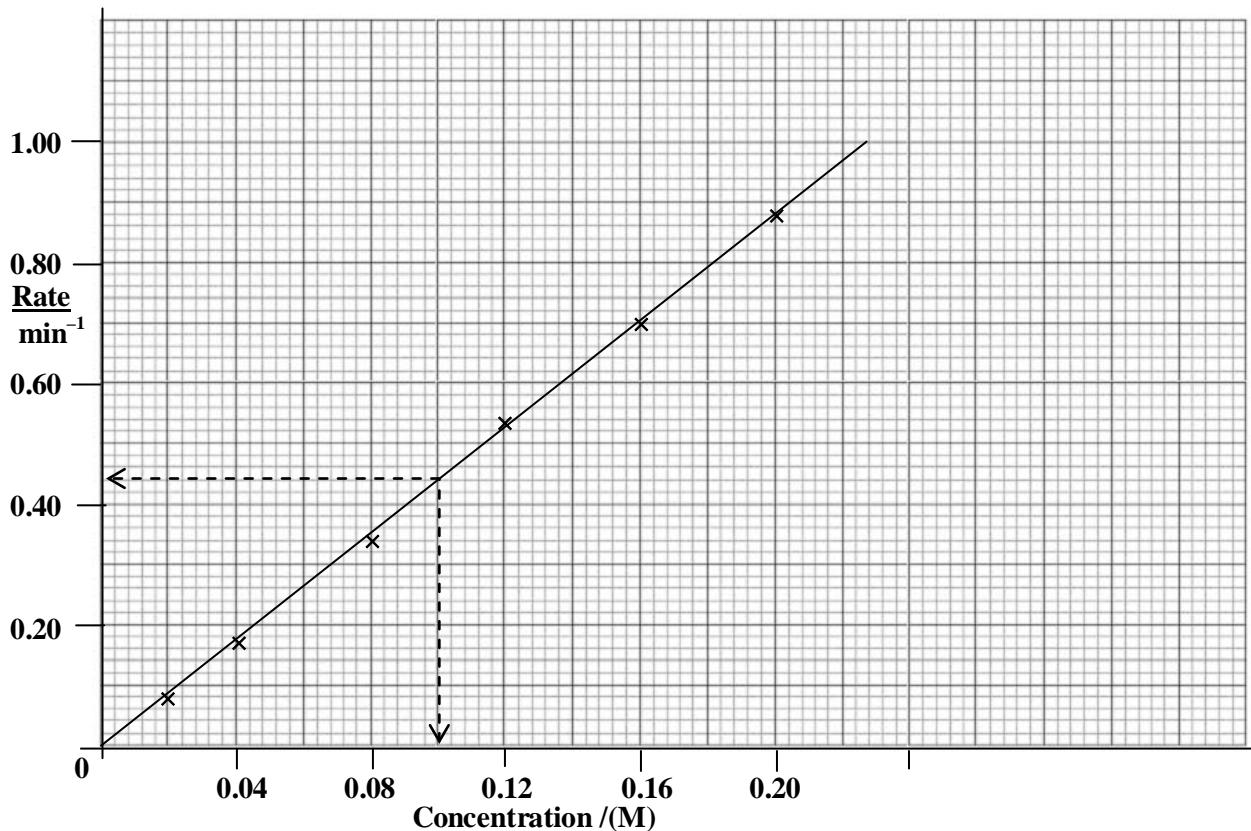
(e) USE: **2.30 ± 0.05** (6)

[Use data from graph; mathematical "slip"– loses 1 mark. Allow 3 marks for reading 1/t value from graph.]

(f) WOULD: **Decrease** (3)

JUSTIFY: Reaction **rate increases with temperature / more collisions reach activation**
energy / more effective collisions (3)

SECTION B

QUESTION 4

Add one mark to the mark awarded to the first two items for which the highest mark is awarded.

(a) WRITE: **$1s^2, 2s^2, 2p^6$ / $[1s^2, 2s^2, 2p^6]^{2-}$ / [He], $2s^2, 2p^6$** [*commas not essential*] (6)

(b) STATE: **Arranged in terms of atomic wgt. (mass) // reversed** some **pairs of elements // left gaps** for undiscovered elements (in the table) **// no noble gases // fewer elements // did not put transition elements (lanthanides, actinides) in separate block** (2×3)

(c) WHAT: **Linear / straight // Bent / angular / V-shaped** (2×3)

(d) GIVE: **2.6×10^{19}** (6)

> $0.0024 \div 56 = 4.29 \times 10^{-5}$ moles of iron   (3)
> $4.29 \times 10^{-5} \times 6 \times 10^{23} = 2.6 \times 10^{19}$ atoms (3)

(e) STATE: **The volumes,** measured at the same temperature and pressure, **of reacting (combining) gases** and their gaseous products **//**
are in (related by) small (simple) **whole number ratios** (2×3)

(f) DEFINE: Minimum **energy of / energy required for //**
collision of reacting particles for reaction to occur **/ to initiate reaction / for effective collision** to occur (2×3)

(g) DISTING.: **Sigma involves end-on** overlap of orbitals **//**
Pi involves side-on (sideways) overlap of p (d or f)-orbitals (2×3)
[Marks may be obtained from diagrams.]

(h) WHAT: **A gas that obeys the gas laws (Boyle's law, kinetic theory, *PV = nRT*) //**
at all values of **temperature and pressure / all conditions / perfectly** (2×3)
[Allow "A gas that obeys the assumptions of the kinetic theory" for 6 mark]

(i) WHAT: **Biological (biochemical, by micro-org., by bacteria, by activated sludge) //**
oxidation (decomposition, digestion) of sewage (carbon containing material) (2×3)

(j) DRAW: **$HC\overset{O}{\diagup\diagdown}OCH_2CH_3$** // **$CH_3C\overset{O}{\diagup\diagdown}OCH_3$** // **$CH_3CH_2C\overset{O}{\diagup\diagdown}OH$** (2×3)
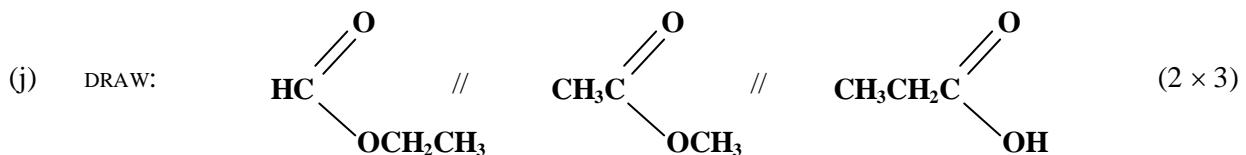
(k) WRITE: **$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$** (2×3)
[Formulae 3 marks; balancing 3 marks]
or
WRITE: **$SO_2 + H_2O \rightarrow H_2SO_3$** (6)
[Allow 3 marks for **$SO_2 + H_2O + {}^{1}/_{2}O_2 \rightarrow H_2SO_4$**]

QUESTION 5

(a) STATE: **Small // indivisible // identical** atomic mass (weight) for particular element (2×4)

(b) NAME: (i): **Thomson //**
(ii): **Rutherford //**
(iii): **Millikan** (3×3)

(c) OUTLINE: **The electron** in a hydrogen atom **occupies (restricted to) fixed energy levels (energy values, discrete energies) //**

an electron in an energy level does not radiate energy //

electron occupies lowest energy levels available / electron occupies ground state //

the electron can move (become excited) to a higher energy **level if it receives** an amount of **energy (photon** of energy) **//**

the photon (energy) must be exactly **equal to the energy difference between the ground state (a lower level) and a higher** energy **level (excited state) //**

the electron in an excited state (a higher level) is unstable //

the excited **electron falls back to a lower** energy **level //**

emitting the excess **energy in the form of a photon of light (h*f*) / emitting light of a definite frequency (wavelength)** / emitting light according to $\mathbf{E_2 - E_1 = h}$*f* **(h*v*)**
[Accept 'quantum' for 'photon' and 'shell' for 'level.']   ANY FOUR: $(6 + 3 \times 3)$

(d) STATE: **Didn't work for higher elements / only worked for hydrogen / doesn't work for multi electron systems //**

Did not take wave-particle duality into account //

Did not allow for uncertainty (probability) //

Did not explain higher resolution spectra / didn't explain discovery of sublevels //

Could not account for the existence of orbitals / Zeeman effect / splitting of spectral lines   (ANY 2×3)

(e) DEFINE: **Region (space)** around the nucleus of an atom **//**
where there is a 99% (high) probability of finding an electron / where electron most **likely to be found //**
or
space occupied by electron // described by solution of Schrödinger equation
                                                                                             (2×3)

DRAW: **Dumbbell drawn**   (3)
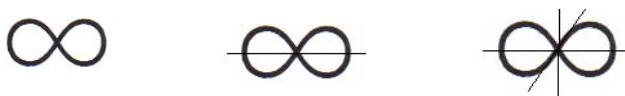
STATE: **two / 2**   (3)

QUESTION 6

(a)   GIVE   **<u>X</u>:**   **Heptane //**

                <u>Y</u>:   **Cyclohexane //**

                <u>Z</u>:   **Methylbenzene**   [(2 × 3) + 2]

(b)   NAME: **Naphtha /** light **gasoline / petrol**   (3)

       WHAT: **Similar carbon number (molecular mass) // similar boiling points**   (2 × 3)

(c)   WHAT: Tendency to **premature ignition (explosion) /** tendency towards **"knocking" /**
                     ignition before spark / ignition before piston reaches top of its ascent   (3)

       NAME: **2,2,4-trimethylpentane /** *iso*-**octane** [Italics and hyphen not required]   (3)

(d)   DEFINE: Energy released (heat change) when **one mole** of a substance **//**
                  is burned (reacts) completely in oxygen / is burned in excess oxygen   (2 × 3)

       OUTLINE: Place **known amount (mass) of substance** in a bomb calorimeter **/ sample in crucible //**

                   Pressurise with oxygen / burn in excess oxygen / burn completely in oxygen /
                   oxygen inlet labelled in diagram //

                   Place bomb in known quantity **water //**

                   Ignite electrically / ignition coil (wire) labelled in diagram //

                   Find heat produced using the rise in temperature and the heat capacity of the

                   system **/ calculate heat produced using** equation $Q = mc\Delta T$ $(Q = C\Delta T)$ **//**

                   From this **calculate the heat produced for one mole** of the substance (ANY THREE: 3 × 3)

(e)   CALC.:   **236.6** kJ mol^{-1} {− 236.6 gets (3) only}   (9)

$C_7H_{16} \rightarrow 7C + 8H_2$	$\Delta H = 224.2$ kJ mol^{-1}	(3)
$7C + 4H_2 \rightarrow C_7H_8$	$\Delta H = 12.4$ kJ mol^{-1}	(3)
$C_7H_{16} \rightarrow C_7H_8 + 4H_2$	$\Delta H = 236.6$ kJ mol^{-1}	(3)
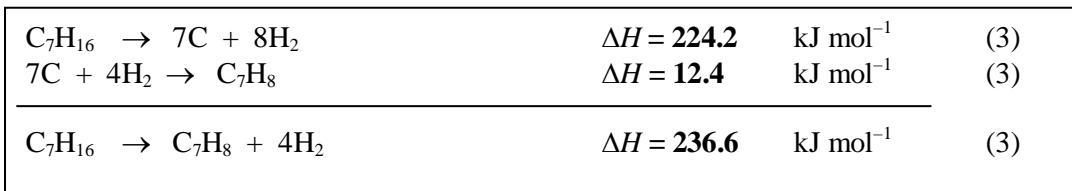
or

$\Sigma \Delta H_{\text{f(products)}}$	−	$\Sigma \Delta H_{\text{f(reactants)}}$	=	$\Delta H_{\text{(reaction)}}$
12.4 (3)	−	(**− 224.2**) (3)	=	**236.6** (3)
OR **12.4** (3)	+	**224.2** (3)	=	**236.6** (3)

       STATE: **Hydrogenation (hardening) of** vegetable **oils (fats) (making margarine) / fuel /**
                  preparation of hydrochloric acid (ammonia, methanol)   (3)

QUESTION 7

(a) EXPLAIN: Rev.:   **Products can react (are reacting) to give back the reactants / is going (can go) in both directions //**

    Equ.:   **A steady state where the concentrations of reactants and products are static / rate of forward reaction = rate of reverse (backward) reaction //**

    Why: **Reactants producing products and products producing the reactants simultaneously /** reaction has **not stopped**   [(2 × 4) + 3]

(b) STATE: If a system **at equilibrium** is disturbed **//**
    it tends to **minimise (oppose, relieve) the disturbance (stress)**   (2 × 3)

    WRITE:
$$\frac{[PCl_3] \cdot [Cl_2]}{[PCl_5]}$$
    (6)

    [*Square brackets required*]
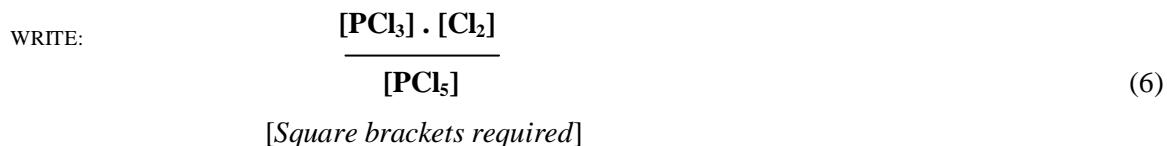
(c) CALCULATE: **0.0225 mol l^{-1}**   (12)

Conversion to moles:	$^{208.5}/_{208.5*} = 1$		$^{53.25}/_{71*} = 0.75$
	PCl$_5$	**PCl$_3$**	**Cl$_2$**
Initially	1* mole	0 moles	0 moles (3)
Next step	1 – x 0.25 moles 0.01* mol	x 0.75 moles 0 moles	x / 0.75* moles / 0 moles (3)
At Equil.	0.0025 moles / l	0.0075 moles / l	0.0075* moles / l (3)

$$\frac{[0.0075] \cdot [0.0075]}{[0.0025]} = 0.0225$$
    (3)

Addition must be shown for error to be treated as a slip (apply only once); consequential marking applies.

(d) IS: **Endothermic / backward (reverse)** reaction is **exothermic**   (3)
    JUSTIFY: **System responds to consume (absorb)** the added **heat**   (3)

(e) WHAT: **K_c will not change**   (3)

    EXPLAIN: The value of **K_c is constant at constant temperature**   (6)
    [Allow 3 marks for **"System responds to increase in pressure by decreasing the the number of molecules** present**"/ "responds by reversing {moving to the left (PCl$_5$)"** // and a further 3 marks for **"according to Le Châtelier's principle (to minimise** the effect of **the stress)" / "which cancels the volume change"**]

QUESTION 8

(a) DEFINE: (i): **Proton (H$^+$) donor //**

(ii): **Related (produced) by gain of one proton (H$^+$) / base + H$^+$** (2 × 4)

DISTINGUISH: Strong acid **dissociates** almost **fully (readily) in** aqueous **solution (water) /**
good proton donor //
weak acid **only slightly dissociates in solution / poor proton donor** (2 × 3)

WHAT: **X$^-$** (3)
["SA diss fully" _and_ "WA diss. slightly" (3); if "in solution (water)" mentioned
once, give other (3).

(b) (i) STATE: **Red** colour observed //

EXPL.: **Equilibrium shifted left** by H$^+$ present **/ high H$^+$ conc. / high [H$^+$]** (2 × 3)

(ii) STATE: **Yellow** colour observed //

EXPL.: **Equilibrium shifted right** by OH$^-$ removing H$^+$ **/ low H$^+$ conc. / low [H$^+$]** (2 × 3)

(c) CALC.: (i): **13** [– log 0.1 = 1 (2)   14 – 1 = 13 (1)] (3)

(ii): **2.9** (6)

|		
[H$^+$]^2/0.004 = 3.5 x 10^{-4} / [H$^+$]^2 = 1.4 x 10^{-6} / [H$^+$] = 1.18 x 10^{-3}		(3)
pH = – log1.18 x 10^{-3} = 2.9		(3)
OR		
pH = – log √(K_a x M) / pH = – log √(3.5 x 10^{-4} x 0.004)		(3)
pH = 2.9		(3)

DRAW.: **Axes labelled (pH – with 7 or 14, and volume – with 25 or 50) //**
Correct shaped curve with steep rise in pH (minimum: 4 to 10) //
Rise around 25 cm^3 (rise around middle of total addition) (3 × 3)
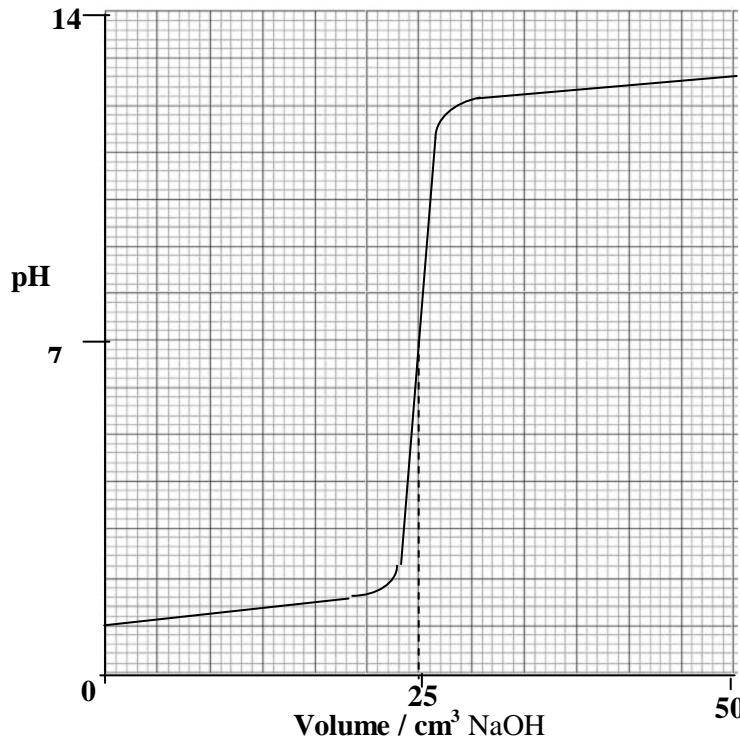
Curve does <u>not</u> have to be drawn on graph paper.

EXPLAIN: **Most indicators will change within this pH range (jump in pH)** (3)

QUESTION 9

(a) NAME: **Ethene / ethylene** (5)
[Allow (3) for C_2H_4]

(b) IDENTIFY: (i): **Y / V** [Accept **W**] **//**

(ii): **Z** (2 × 3)

(c) DESCRIBE: **Heterolytic fission** of hydrogen chloride molecule / $HCl \rightarrow Cl^- + H^+$ **//**

Addition (attraction, bonding) of H^+ ($H^{\delta+}- Cl^{\delta-}$) to the double bond //

Forming a localised **carbonium* ion (carbocation*)** / *Accept positive carbon (C^+)

//
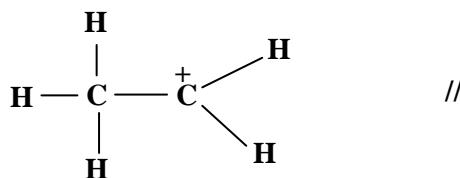
Addition of Cl^- to the carbonium ion (C^+) to give chloroethane (4 × 3)
[Note: Where appropriate, allow correct use of 'curly' arrows.]

(d) STATE: (i): **H_2** Accept H_2 & condition reversed e.g. Ni/H_2. (6)
If reagent omitted (or incorrect), give (3) if a correct
condition {Ni, Pd, Pt, heat (140°)} is given.

(ii): **Cl_2 // hf (hν) / ultraviolet (uv)** light / **sunlight / heat** (2 × 3)

(e) DRAW: **Apparatus correctly drawn //**

Ethanol held in glass wool (in labelling) //

Aluminium oxide correctly placed and heated (in labelling) (3 × 3)
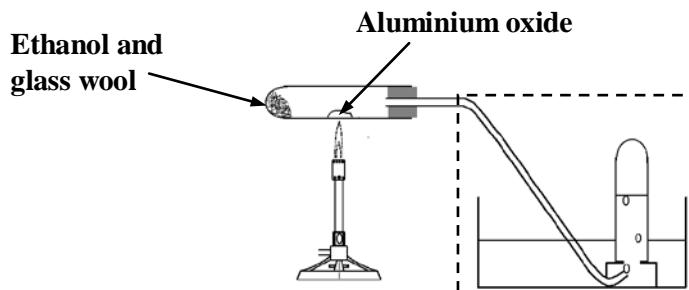
[Note: The collection part of the diagram (the part in the box) is not required.]

(f) (2 × 3)

[Allow **CH_2ClCH_2Cl** and **$CH_2=CHCl$**]

QUESTION 10

(a) DEFINE: **Relative (measure of) attraction / number expressing attraction //**
an atom of an element has **for a shared pair of electrons (for a pair
of electrons in a covalent bond**   (2 × 3)

   STATE: **Increasing effective nuclear charge //**
Decreasing atomic radius   (2 × 3)

   STATE: **H₂O // NH₃**   (2 × 3)

   JUSTIFY: **Hydrogen bonded to small highly electronegative element (bonded to O, N, F)**
[If either one of "small / highly" omitted (– 1)]   (3)

   SUGGEST: **Weaker (less effective)** hydrogen bonding in ammonia **/ stronger (more
effective)** hydrogen bonding **in water / smaller electronegativity difference
for NH bond / bigger electronegativity difference for OH bond / electroneg-
ativity lower for N** than O **/ electronegativity higher for O** than N **/ NH bond
less polar** / **OH bond more polar / ratio of lone pairs to H atoms in water
is 1:1**   (4)

(b) (i): DESC.: **Sample in** sealed **melting point tube / sample on heating block //**
**Melting point tube strapped (attached) to thermometer / in MP apparatus
with thermometer / thermometer in** melting **block //**
Immersed in liquid paraffin* / block being heated / heat in MP app. //
Note temperature range over which (or temp. at which) sample melts
                                                                                                                      [6 + (2 × 3)]

   [*No diagram deduct 3 marks*] *Or other suitable liquid (not water)

   (ii): GIVE: **Higher melting point //** melting point **closer to correct (in tables) value //
sharper (narrower range)**   (2 × 3)

   (iii): NAME: **Infra red (IR)** spectroscopy   (3)

   (iv): GIVE: Food **preservative / disinfectant (antiseptic, fungicide) / calibration**   (4)

(c) (i): DEDUCE: **+6 / 6 / VI // +3 / 3 / III**   (4 + 3)

   (ii) STATE: **Orange to green**   [Accept 'yellow' for 'orange']   (3)
[*Both colours required*]

   (iii) DESC.: **Heat (warm) with //**

   Fehling's solution / Ammoniacal silver nitrate (Tollens' Reagent) //

   Brick-**red** precipitate results **/ silver** mirror   (3 × 3)
[*Observation must match test*]

   (iv) GIVE: **Ethanoic acid / acetic acid //**   [Accept 'ethyl ethanoate / ethyl acetate.']

                                                                                                                           (2 × 3)

   [Accept **CH₃COOH**]

QUESTION 11

(a)   (i)   NAME: **Platinum** [Accept carbon / graphite]   (4)

(ii)   HOW: Movement of **ions**   (3)

(iii)   WHICH: **B**   (3)
WRITE: $H_2O \rightarrow 2H^+ + \frac{1}{2}O_2 + 2e^-$ (6)
[Formulae (3), Balancing (3)]

(iv)   WHAT: **17**   (3)

(v)   WHICH: **A**   (3)
JUSTIFY: **Because OH⁻ are generated**   (3)

(b)   DEFINE (i):   **Spontaneous** random **decay of (disintegration of, decomposition of, breaking up of, change within) a nucleus // to release** α, β or γ **radiation**   (3 + 2)
or
Spontaneous random **emission of radiation (radiant energy, rays, particles) // from unstable nuclei / due to decay of (disintegration of, decomposition of, breaking up of, changes within) a nucleus**   (3 + 2)

(ii):   **Time taken for half of the** radioactive **isotopes (atoms, nuclei, nuclides) //** in a sample **to disintegrate (decay)**   (3 + 2)
or
time for sample to reach half its activity   (5)
or
Half-life formula: $t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ (3)
meaning of λ   (2)

DETERMINE: A = **237** // Z = **93**   (2 × 3)

STATE: Causes **ionisation /** causes **cancer /** causes **mutation**   (3)

EXPLAIN: Radiation **is not very penetrating**   (3)

EXPLAIN: **Half life is over 400 years** (very **long**) **// sample does not deplete quickly**   (3)

(c) **A** (i)   **Tetrahedral // covalently bonded** carbon **atoms** form strong crystals (2×3)

       (ii)   **Layers of hexagonally bonded** carbon **atoms / weak forces between layers // layers can slide over each other** (2×3)

       (iii)   **Delocalised // electrons free to move** along the layers (2×3)

       GIVE: **Covalent**   (3)

       WHAT: **Bragg**   (4)

B (i) WHAT: **Dust / moisture / carbon dioxide**   (4)

       (ii) DESCRIBE: Relevant **diagram with one correct label //**

                        Compressed (liquid) air warms up in column //

                        liquid **oxygen** (highest boiling point) collects **at base of column** and is removed / gaseous **nitrogen** (lowest boiling point) comes off **at top of column** (3×3)
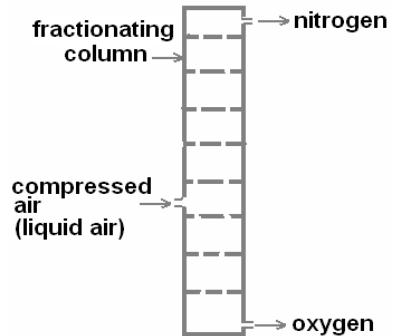
       (iii) EXPLAIN: **Continuous //**
                        Air goes in at one end and product comes out at the other in a continuous manner (2×3)
                        Air is cooled and fractionated continuously [Give the two (3)s for this.]

       (iv) NAME: Liquid **nitrogen / neon / argon / krypton / xenon**   (3)

             USE: Nitrogen: **Inert atmosphere (or example) / fast freezing of fruit (sperm samples) / gas chromatography / spectroscopy**

                        Neon: **Inert atmosphere (or example) / lighting (lasers) / tv tubes / refrigerant**

                        Argon: **Inert atmosphere (or example) / lighting (lasers / MRI / CT)**

                        Xenon: **Inert atmosphere (or example) / photography / lighting (lasers) / MRI /CT**   (3)
                        [Use must be matched with named co-product]