State Examinations Commission

Scéimeanna Marcála Scrúduithe Ardteistiméireachta, 2004

Ceimic Ardleibhéal

Marking Scheme Leaving Certificate Examination, 2004

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. Note, however, that words, expressions or phrases must be correctly used in context and not contradicted, and where there is evidence of incorrect use or contradiction, the marks may not 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.
Outline Marking Scheme

Section A [At least two questions must be answered from this section]

1. (a) Name 4, Col. Change 4; (b) Describe \(6 \times 3\); (c) Solution 3, 3; (d) Calculate (i) 9, (ii) 3, (iii) 3; (e) Equation: formulas 3, balancing 3.

2. (a) Function 5, Identify 3, Describe 3; (b) Precautions \(2 \times (2 \times 3)\); (c) Equation 6; (d) Unsatd. 3, Test \(3 \times 3\); (e) Flame 3, Equation: formulas 3, balancing 3.

3. (a) (i) 5, (ii) Insoluble \(2 \times 3\), Soluble \(2 \times 3\); (iii) 3, (iv) 3, (v) 3; (b) (i) \(6 + 3 \times 3\), (ii) \(2 \times 3\), (iii) (3).

Section B

4. Eight items to be answered. Six marks are allocated to each item and one additional mark is added to each of the first two items for which the highest marks are awarded.

(a) \(2 \times 3\); (b) \(2 \times 3\), (c) 6; (d) \(2 \times 3\); (e) (i) 3, (ii) 3; (f) 6, (g) (i) 3, (ii) 3; (h) 6; (i) State 3, Explain 3; (j) \(2 \times 3\); (k) A \(2 \times 3\), B \(2 \times 3\).

5. (a) Config. 5, Diagram 3, Describe \(2 \times 3\), Type 3, 3; (b) Define \(3 \times 3\), State 3, 3, Account \(2 \times 3\), Explain 6 or 2 \(\times 3\), 3.

6. (a) (i) 5, (ii) 6; (b) Calculate 12; (c) Properties \(2 \times 3\), Why 3; (d) Outline \(6 + 2 \times 3\); (e) Identify \(2 \times 3\).

7. (a) Identify \(2 \times 4\); (b) Names & Type One point 6, two points 12, three points 15; (c) (i) – (iv) First correct point 6, other five points 5 \(\times 3\); (d) Uses ANY TWO: \((2 \times 3)\)

8. (a) Define 5, Explain 3; (b) Name A 3, B 3, Copy \(2 \times 3\); (c) Elements \(2 \times 3\), Poison 3; (d) Observe \(4 \times 3\), Explain \(2 \times 3\).

9. (a) Equil. 5, Dynamic 3; (b) Predict 3, 3, Reason (i) 3, (ii) 3; (c) Are 3, Explain 3; (d) Effect 6; (e) \(K_c\) 6, Calc. 12.

10. (a) (i) 10, (ii) 9, (iii) 6. (b) Describe \(4 + 3 \times 3\), (i) \(2 \times 3\), (ii) 3, (iii) 3. (c) State 3, 2; (i) 3, 2, (ii) 3, (iii) 12.

11. (a) Define \(2 \times 3\), (i) \(2 \times 3\), (ii) 6, (iii) 3, 4. (b) Define 7, (i) \(2 \times 3\), (ii) 12. (c) A (i) 4, (ii) 3; Type 3, Forces 3, Explain (i) \(2 \times 3\), (ii) \(2 \times 3\). B (i) 4, 3, (ii) 3, (iii) 3, (iv) 3, (v) \(3 \times 3\).
SECTION A

At least two questions must be answered from this section.

QUESTION 1

(a) NAME: **eriochrome black T (solochrome black)**

[Accept *eriochrome or eriochrome T; likewise for solochrome*]

COL. CHANGE: wine **red (wine) to deep blue** [Given independently of NAME]

(b) DESCRIBE: 
- rinse with deionised water
- rinse with reagent (solution)
- clamp vertically
- use funnel when adding reagent / remove funnel after filling
- open tap to fill below tap (tip, jet, nozzle) / remove air bubbles [Allow 'tap is full']
- set bottom of meniscus on mark / read bottom of meniscus

ANY FOUR: (6 + 3 × 3)

(c) SOLUTION: buffer

**to keep pH above 9 / to keep pH at (around) 10 / ensure sharp (accurate) end-point**

[Accept ‘to keep pH at a certain value (from changing)’]

(d) CALCULATE: (i) **0.00081 mol l⁻¹**

\[
\frac{100 \times X}{1} = \frac{8.1 \times 0.01}{1} \quad / \quad 100 \times X = 8.1 \times 0.01
\]

\[
X = \frac{0.00081}{1} = 0.00081 \quad \text{(3)}
\]

(ii) **0.081 g l⁻¹**

\[
0.00081 \times 100^* = 0.081 \quad \text{(3)}
\]

[*100 essential unless calculation shown e.g. 40 + 12 + 3 x 16 = 98 (slip)]

(iii) **81 p.p.m.**

\[
0.081 \times 1000 = 81 \quad \text{(3)}
\]

(e) EQUATION: **CaCO₃ + 2HCl → CaCl₂ + H₂O + CO₂ /**

\[
\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2
\]

CaCO₃ + 2HCl → CaCl₂ + H₂CO₃  Formulas (3)  Balancing (3)
QUESTION 2

(a) FUNCTION: keeps (holds, soaks up) ethanol (liquid, reagent) at end of test tube / avoid wetting the aluminium oxide (5)

IDENTIFY: aluminium oxide / alumina / Al₂O₃ (3)

DESCRIBE: white powder (solid) [Given independently of IDENTIFY] (3)
[Do not allow grey or other colours]

(b) PRECAUTIONS: first precaution (3) explanation (3); second precaution (3) explanation (3)

keep gas away from flames (3) gas is flammable / risk of explosion (3)
air-tight stopper (secure assembly) (3) stops ethene escaping / prevents fire (explosion) (3)
safety screen (glasses) (3) risk of explosion (3)
taking tube from water / disconnecting tube / dismantling (3) to prevent suckback (3)
tongs (gloves, glass rod) (3) skin sensitive to glass wool (3)
avoid inhalation of glass wool (wear mask) (3) glass wool a lung irritant (3)
tongs (heat resistant gloves) (3) prevent burns (can be inferred here) (3)

Must be matched
[Accept general procedural precautions for 3 marks only e.g. ‘heat gently at first’,
‘take care in inserting glass tubing in bungs’, ‘heat Al₂O₃ directly’, ‘don’t heat ethanol with naked flame’ ]

(c) EQUATION: \( \text{C}_2\text{H}_5\text{OH} \rightarrow \rightarrow \text{C}_2\text{H}_4 + \text{H}_2\text{O} \) / \( \text{C}_2\text{H}_5\text{OH} \underset{\text{Al}_2\text{O}_3}{\rightarrow} \rightarrow \text{C}_2\text{H}_4 + \text{H}_2\text{O} \) (6)

| Allow: \( \text{C}_2\text{H}_5\text{OH} \rightarrow \rightarrow \text{C}_2\text{H}_4 \) |
| \( \text{C}_2\text{H}_5\text{OH} \underset{\text{H}_2\text{O}}{\rightarrow} \rightarrow \text{C}_2\text{H}_4 \) [Accept if written with + \( \text{H}_2\text{O} \)] |
| \( \text{C}_2\text{H}_5\text{OH} + \text{Al}_2\text{O}_3 \rightarrow \rightarrow \text{C}_2\text{H}_4 + \text{H}_2\text{O} + \text{Al}_2\text{O}_3 \) |

[Allow (3) for correct formulas of both ethanol and ethene as reactant and product]

(d) UNSATD: double / triple / multiple bond (carbon-to-carbon bond) present / undergoes addition reactions (3)

TEST: add bromine water (solution) (3) add (bubble through, shake with) (3)
red / orange / yellow (3) OR bromine water (3)
[Accept ‘red-brown’ but not ‘brown’ ]
to colourless (3) decolorises (not ‘goes clear’) (3)

(e) FLAME: yellow / luminous (bright) / slightly smoky (sooty) flame (3)
[‘clean’ not acceptable but does not cancel a correct answer]

EQUATION: \( \text{C}_2\text{H}_4 + 3\text{O}_2 \rightarrow \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O} \) Formulas (3) Balancing (3)
QUESTION 3

(a) (i) so that crystals will form on cooling / so that benzoic acid does not remain in solution on cooling / to maximise yield / to minimise what stays dissolved in the solvent / so that hot solution is saturated / keep solution as concentrated as possible

[Allow ‘concentrated’ for 3 marks only] (5)

(ii) insoluble: filtration of hot solution / first filtration remained on filter paper (in funnel) / not able to pass through

soluble: filtration of recrystallised benzoic acid / cold filtration / second filtration passed through filter paper (funnel) / stayed in (retained by) mother liquor (solution, filtrate) (3)

(iii) let solution cool fully (efficiently) / cool in ice-water (crushed ice) / evaporate more solvent (water) [Accept check if m.p. is sharp] (3)

(iv) leave in warm place (on radiator) / in desiccator / in oven at 100 °C

[Accept ‘leave on filter paper (air dry)’, also a specified suitable warm place.] (3)

(v) 90 %

\[
\frac{2.25 \times 100}{2.5} = 90
\] (3)

(b) (i) correct diagram with instrument for measuring temperature including one valid label

melting point apparatus with thermometer
thiele tube (beaker) containing liquid with thermometer
aluminium block with thermometer (temp. probe labelled if used)

detail of setting up

sample in melting point tube for melting point apparatus and thiele tube (beaker)
sample on aluminium block or in melting point tube for aluminium block

[Stated or labelled in diagram]

method of heating *

electrical in melting point apparatus
bunsen (hotplate) and suitable liquid (e.g. liquid paraffin / oil) for thiele tube (beaker)
bunsen (hotplate) for aluminium block

[Can be got if shown on diagram – even if unlabelled]

heat slowly (gently)*

observe (note) the substance as it is heated*

note temperature (range) at which it melts

* Accept only two from these three points

FOUR POINTS: (6 + 3 x 3)

(ii) lower

less sharp / melting over wider (broader) range of temperatures (3)

(iii) preservative (E2--) / disinfectant (antiseptic, biocide, fungicide) / calibration of thermometers for melting point apparatus (3)
SECTION B

QUESTION 4

Eight items to be answered. Six marks to be allocated to each item and one additional mark to be added to each of the first two items for which the highest marks are awarded.

(a) average mass of atoms of element (3) relative to (based on) \( \frac{1}{12} \) mass of carbon-12 atom (3)

(b) NH\(_3\) has three bond pairs and one lone pair (shown/stated) (3) BF\(_3\) has three bond pairs (shown/stated)(3) [Allow ammonia has a lone pair of electrons for 6 marks]

(c) oxygen: / Stronger intermolecular (Van der Waals', London, dispersion, dipole-dipole) forces (6)
   [Allow higher molecular mass or bigger electron cloud (more electrons) for 3 marks only]
   [or opposite points for hydrogen]

(d) volume varies directly with kelvin (absolute) temperature / \( \frac{V}{T} = k \) / \( \frac{V_1}{T_1} = \frac{V_2}{T_2} \) / \( V \propto T \) / rate of expansion of a gas is \( \frac{1}{273} \) of its volume at 0 °C for every degree Celsius rise in temperature for a definite mass of gas at constant pressure * must be capital letter. (3)

(e) (i) H\(_2\)PO\(_4\)\(^-\) (3) (ii) PO\(_4\)\(^{3-}\) (3)

(f) precipitation / tertiary treatment [Accept coagulation or flocculation] (6)
   [Accept a suitable precipitating agents for 3 marks only]

(g) (i) – 1 (3) (ii) + 5 / 5 / V (3)

(h) 70 % [No penalty incurred if Ar values from Periodic Table used] (6)

\[
\begin{array}{c|c}
112 & 160 \\
\hline
\end{array}
\]

\( \frac{112}{160} \times 100 = 70 \) (3)

(i) State: purple (violet, pink) (3)
   Explain: hydroxyl ions produced / pH increases around (near) electrode / alkaline (3)

(j) white precipitate (cloudiness) with barium chloride (barium nitrate, barium ions) solution which dissolves (disappears) in dilute hydrochloric acid (HCl) [Given independently of reagent used] (3)

(k) A liquefaction / fractional distillation / using diffusion of air (3)
   Electrolysis of acidified water (3)
   B thickens (thick) protective layer of oxide on surface (3)
QUESTION 5

(a) CONFIG: 1s²2s²2p¹⁵ \[Allow (5) for 1s²2s²2p³\]  (5)

Diagram: \[
\times \text{N} \equiv \text{N}:
\]
\[
\text{:N::N: / :N:::N: / :N;\equiv;N:}
\]  (3)

[Accept diagrams as above with all dots or all crosses]

Describe: one sigma (σ)  (3) two pi (π)  (3)
[No marks for two and one unless names (symbols) given]

Type: Van der Waals / London / Dispersion / Dipole-dipole  (3)
molecule is non-polar / pure covalent / temporary (non-permanent, transient forces) / due to temporary distortion of the electron cloud  (3)

(b) Define: the minimum energy to remove most loosely-bound (highest energy, outermost) electron from an isolated (gaseous) atom in its ground (lowest energy) state  (3)

State: increase in nuclear charge (atomic number)  (3) decrease in atomic radius  (3)

Account: nitrogen stable  (3)
due to half-full p sublevel (subshell) / due to three half-full p orbitals / due to 1s²2s²2p³ / due to 2p₁²2p₂¹  (3)
OR
oxygen less stable  (3)
due to pair of electrons in one p orbital / due to 1s²2s²2p⁴ / due to 2p₁²2p₂¹ / one electron away from stable (loss of electron makes stable)  (3)

Explain: sodium: First electron removed from third (outer, 3s) shell (level) whereas second removed from second (inner, 2p) shell (level)  (6)

 loss of first gives high stability configuration [full outer level (full outer shell), noble gas (Ne) configuration, outer (stable) octet (2s²2p⁶)]  (3)
 loss of second from high stability configuration [new (inner) level (shell), full level (full shell), noble gas (Ne) configuration, outer (stable) octet, 2s²2p⁶ (not full 2p)]  (3)

Neon: second from same sublevel (subshell) / first removed from full (stable) shell (level) and second removed from same shell (level) / both removed from 2p  (3)
QUESTION 6

(a) (i) heat (energy) when 1 mole of compound formed from its elements \( (3 + 2) \)

(ii) measure of (indication of, showing, giving) tendency (likelihood) to auto-ignite (knock, pink, pre-ignite, ignite early, ignite before spark) / number representing ability of fuel to resist auto-igniting (knocking, pinking, pre-igniting, igniting early, igniting before spark) \( (6) \)

\[ \text{or} \]

based on a scale where 2,2,4-trimethylpentane (iso-octane) is assigned a rating of 100 and heptane (n-heptane) a value of 0. \( (6) \)

Percentage by volume of 2,2,4-trimethylpentane (iso-octane) in a blend (mix) with heptane (n-heptane) that matches the behaviour of the fuel in terms of auto-ignition \( (6) \)

(b) CALC.: \(-75.6 \text{ kJ mol}^{-1}\) \( (12) \)

\[
\begin{align*}
C + O_2 & \rightarrow CO_2 \quad \Delta H = -394 \text{ kJ mol}^{-1} ; \quad H_2 + \frac{1}{2}O_2 \rightarrow H_2O \quad \Delta H = -286 \text{ kJ mol}^{-1} \\
2H_2 + O_2 & \rightarrow 2H_2O \quad \Delta H = -572 \text{ kJ} \quad (3) \\
CO_2 + 2H_2O & \rightarrow CH_4 + 2O_2 \quad \Delta H = 890.4 \text{ kJ} \\
C + 2H_2 & \rightarrow CH_4 \quad \Delta H = -75.6 \text{ kJ mol}^{-1} \quad (3)
\end{align*}
\]

\[ \text{OR} \]

\[
\Delta H_{\text{(reaction)}} = \Sigma \Delta H_{\text{f(products)}} - \Sigma \Delta H_{\text{f(reactants)}} \\
-890.4 \quad (3) = [-394 \quad (3) - 572 \quad (3)] - [\Delta H_{\text{f(methane)}} + 0] \\
\Delta H_{\text{f(methane)}} = -394 - 572 + 890.4 = -75.6 \text{ kJ mol}^{-1} \quad (3)
\]

[Allow 3 marks only for +75.6 kJ mol\(^{-1}\) ]

(c) PROPS: high kilogram cal. value (high energy output, high heat of combustion) / clean (non-polluting, burns to produce carbon dioxide and water) / non-toxic / plentiful / relatively cheap / can be piped (easily distributed) \[ \text{Do not accept 'easily distributed in tanks'} \quad \text{ANY TWO: (2 x 3)} \]

WHY: to give an odour (smell) / to detect leaks / to make safe \( (3) \)

(d) OUTLINE: crude oil heated (evaporated) / crude added continuously at bottom

vapour (gas) passes up through tower (column) / fractionating tower with trays

fractions condense (separate, taken off) at different levels (up along tower)

depending on their boiling points / high b.p. fractions at bottom / low higher up / heavier at bottom / lighter at top / or named exemplar to indicate this \[ \text{ANY THREE: (6 + 2 x 3)} \]

[The first three points can be got from a diagram; the last point must be specified in words or clearly written on the diagram.]

(e) IDENTIFY: chain length / branching / rings (cyclic) / aromatics \[ \text{ANY TWO: (2 x 3)} \]
QUESTION 7

(a) IDENTIFY:  
- planar carbon  
- tetrahedral carbon  

(b) NAMES:  
- alcohol: methanol (methyl alcohol)  
- carboxylic acid: propanoic acid (propionic acid)  

TYPE: substitution / condensation / dehydration  

(c) (i) propan-1-ol / 1-propanol / propyl alcohol / \( n \)-propanol / correct formula  
[Accept propanol]  
(ii) propanal (propionaldehyde)  

(iii) oxidation / redox / dehydrogenation and oxidation  
[No marks for 'dehydrogenation' on its own]  

(iv) sulfuric acid (H$_2$SO$_4$) / acidified / H$^+$  

sodium (potassium) dichromate (chromate) (VI) / potassium manganate (VII) / potassium permanganate / correct formula  

(d) USES:  
- perfumes (scents) / cosmetics / flavourings (essences) / soap making / drugs (aspirin, paracetamol, amyl nitrite, etc.) / anaesthetics (novocaine, benzocaine, etc.) / insecticides (malathion, pyrethrin, etc.) / clothing (named item) / sails / seat belts / plastics (perspex) / rubs (oil of wintergreen) / solvents for (production of) varnishes (lacquers, enamels, adhesives, glues, paints, inks, etc.) / energy storage / lowering cholesterol / aromatherapy / synthetic fibres / cooking / soap  
 ANY TWO: (2 x 3)
QUESTION 8

(a) DEFINE: change in concentration per unit time / rate of change of concentration /

\[ \text{change in concentration} \quad \text{time} \quad \] [Do not accept ‘mass’, ‘volume’, ‘quantity’, ‘amount’ in place of concentration] (5)

EXPLAIN: More (greater number of) collisions reach (exceed) activation energy / more collisions have enough energy for reaction / more effective collisions

[Allow (3) for ‘greater number of high energy collisions’, ‘increases energy (velocity, speed) of particles (molecules, reagents, collisions)’ or ‘more collisions’ or ‘more molecules have the activation energy’] (6)

(b) NAME: A: Activation energy [Accept $E_a$ or $E_{act}$] (3)

B: Heat of reaction / Heat change / $\Delta H$ / Heat absorbed / Enthalpy change

[Accept ‘energy’ for ‘heat’] (3)

COPY:

Reduction in activation energy shown (3)

Products line shown above reactants line / same $\Delta H$ with and without catalyst (3)

(e) ELEMENTS: platinum / palladium / rhodium [Allow symbols] ANY TWO: (2 x 3)

POISON: lead [lead compounds e.g tetraethyllead (TEL)] / sulfur (sulfur cpds.) [Allow symbols] (3)

(d) OBSERVE: pink at start of reaction [Accept red] (3)

then bubbling (effervescence, fizzing, gas produced) as (3)

reaction mixture turns green (3)

reaction finishes and mixture turns pink again (3)

EXPLAIN: Colour change (change from pink to green) indicates formation of new substance

Change back to original colour (pink) suggests it is an intermediate

Bubbling while green suggests intermediate is reacting [Accept Changes colour and changes back indicates intermediate] (6)
QUESTION 9

(a) EQUIL: state in which rate of forward reaction = rate of reverse (backward) reaction  
[Allow 5 marks for \( R_f = R_{rev} \)]  

DYNAMIC: reaction has not stopped / reaction continuing / product forming and returning to reactants constantly  

(b) PREDICT: low temperature (3) high pressure (3) 
OR high pressure (3) and low temperature (3)  

REASON: (i) forward (ammonia producing) reaction is exothermic (produces heat, raises temp.) (3) 
(ii) forward (ammonia producing) reaction goes to fewer molecules (smaller volume, alleviates or lowers pressure) [Marks for (i) and (ii) can be given independently of PREDICT] (3)  

(c) ARE: No / high temperature is used / compromise temperature / specified high temperature] (3)  

EXPLAIN: at low temperatures rate is too low (slow) / activation energy too high (3)  

(d) EFFECT: lowers activation energy / increases rate for both / catalyses both / reaches equilibrium faster / equilibrium position unaffected / forward and reverse rates equally affected (6)  
[Allow 3 marks only for ‘increases rate’]  

(e) \( K_c: \) \[\frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}\] (6)  
CALC: 0.4 \( l^2 \) mol\(^{-2}\) (\( M^{-2}\)) [or answer that rounds off to 0.4] (12)  

\[
\begin{array}{ccc}
\text{N}_2 & + & 3\text{H}_2 & \rightleftharpoons & 2\text{NH}_3 \\
6 \text{ mol} & 18 \text{ mol} & 0 \text{ mol} \\
3 \text{ mol} & 9 \text{ mol} & 6 \text{ mol} & (3) \\
\div 5 & 0.6 \text{ } M & 1.8 \text{ } M & 1.2 \text{ } M & (3)
\end{array}
\]

\[ K_c = \frac{(1.2)^2}{(0.6)(1.8)} = 0.4 \]

OR  

\[
\begin{array}{ccc}
\text{N}_2 & + & 3\text{H}_2 & \rightleftharpoons & 2\text{NH}_3 \\
6 \text{ mol} & 18 \text{ mol} & 0 \text{ mol} \\
\div 5 & 1.2 \text{ } M & 3.6 \text{ } M & 0 \text{ } M & (3) \\
0.6 \text{ } M & 1.8 \text{ } M & 1.2 \text{ } M & (3)
\end{array}
\]

\[ K_c = \frac{(1.2)^2}{(0.6)(1.8)} = 0.4 \]
QUESTION 10: Answer two of the parts (a), (b) and (c).

(a) (i) MOLES: Allow 24.60 to 25.00 mol

\[
\begin{align*}
36\% \text{ (w/v)} &= 36\ g \text{ in } 100\ \text{cm}^3 / 360\ g\ l^{-1} \\
&\times 36.5 \div 100 \\
&\times 2.5 \div 36.5 \\
&0.99\ mol \ / \ 900\ g \ / \ 9.9\ mol \\
&\downarrow 2500/100 \downarrow 36.5 \downarrow 2.5 \\
&24.75 \ / \ 24.66 \ / \ 24.75 \ (4 + 2 \times 3)
\end{align*}
\]

(ii) Allow 1303.80 to 1325.00 g

\[
\begin{align*}
24.60 \text{ to } 25.00\ mol\ HCl &= 12.30 \text{ to } 12.50\ mol\ Na_2CO_3 \quad (3) \\
12.30 \text{ to } 12.50 \times 106^* &= 1303.80 \text{ to } 1325.00 \quad (6) \\
[\text{[*106 essential unless calculation shown e.g. } = 2 \times 23 + 12 + 3 \times 16 = 107 \text{ (slip)}]
\end{align*}
\]

(iii) Allow 295.20 to 300.00

\[
\begin{align*}
24.60 \text{ to } 25.00\ mol\ HCl &\rightarrow 12.30 \text{ to } 12.50\ mol\ CO_2 \quad (3) \\
12.30 \text{ to } 12.50 \times 24 &= 295.20 \text{ to } 300.00 \quad (3) \ [\text{Give (0) if 22.4 used]}
\end{align*}
\]

(b) DESCRIBE: electrons in ground state / electrons restricted to energy levels (energy values, discrete energies) / energy level diagram / energy of electron quantised

- fixed energies (photons) absorbed / jump (move, promoted) to higher level(s) (excited state) / energy only emitted (absorbed) when electrons move between fixed levels
- excited state unstable / electrons fall back to lower levels / electrons fall back emitting energy as light (electromagnetic energy, photons) / emitting discrete packets (photons) of energy
- energy difference between levels gives specific (definite) frequency (wavelength, line) of light in spectrum / energy of photons dictated by energy gap between levels / \( E_2 - E_1 = h\nu \)

(i) each element has a different distribution (set, arrangement) of energy levels / different electron configurations

- giving rise to different electron transitions

[Allow due to different numbers of electrons and nuclear charge / different attractions between electrons and nucleus (different electrostatic attractions) \( \text{for 3 marks only]}

(ii) atomic absorption spectrometry (AAS) \( \text{[Accept the spelling 'absorption]} \)

(iii) only worked for simple (hydrogen, hydrogen-like) species (atoms) / wave nature of electron (wave-particle duality) / Heisenberg uncertainty principle (or its statement) / discovery of sublevels (subshells) / could not explain Zeeman effect / didn’t explain splitting of lines
Question 10 continued/

(c) **STATE:** equal (same) volumes of gases contain equal (same) numbers of molecules (particles, moles) (3)

under same conditions of temperature and pressure (2)

[Allow ‘1 mole of a gas occupies 22.4 l at stp for 3 marks only’]

(i) perfectly obeys the gas laws (Boyle’s law, the kinetic theory, PV = nRT) (3)

under all conditions of temperature and pressure (2)

(ii) polar / intermolecular forces (attractions between molecules, named intermolecular force) / molecules have volume (volume of molecules not negligible) / collisions not perfectly elastic

ANY ONE: (3)

(iii) 0.12 litres

\[
\begin{align*}
PV &= nRT \\
V &= \frac{nRT}{P} \\
T &= 20 + 273 = 293 \text{ K} \\
P &= 101 \times 10^0 = 1.01 \times 10^5 \text{ Pa} \\
n &= \frac{0.29}{58} = 0.005 \text{ mol} (3) \\
V &= \frac{0.005 \times 8.3 \times 293}{1.01 \times 10^5} = 0.00012 \text{ m}^3 (3) \\
0.00012 \times 1000 &= 0.12 \text{ litres} (3)
\end{align*}
\]

QUESTION 11: Answer any two of the parts (a), (b) and (c).

(a) **DEFINE:** spontaneous (random) emission of radiation (radiant energy, rays) (3)

[Accept ‘...of α, β and γ particles’ but not ‘...particles’ on its own]

from unstable nuclei / [Allow due to disintegration (breaking up, decomposition) of nuclei] (3)

(i) negative (minus) charge / negligible (around \(1/1840\) or 0.00054) mass / high speed / more penetrating than α (less penetrating than γ, stopped by 2 – 5 mm (sheet of) aluminium, moderately penetrating) / less ionising than α (more ionising than γ, moderately ionising) / damage body cells (cause cancer) / electrons from nucleus / deflected by electric fields / deflected by magnetic fields / fluorescence / phosphorescence

ANY TWO: (2 x 3)

(ii) \[ \begin{array}{c}
14 \\
6
\end{array} \xrightarrow{0} \begin{array}{c}
0 \\
7
\end{array} + \begin{array}{c}
14 \\
-1
\end{array} \] [Allow with atomic numbers on top and mass numbers below but not mixed] (6)

[Allow (3) for identifying nitrogen as a product] [Allow \(0\) for \(e\)]

(iii) In living things, the ratio of carbon-12 to carbon-14 is constant (same as in air) (3)

[Accept ‘C-14 constant during life’ or ‘C-14 replaced (taken in) during life’]

After death, carbon-14 decays and the changed ratio and the half-life used to find age / decrease in carbon-14 related to time passed since death (4)
Question 11 continued/

(b) **DEFINE:** minus log (negative log) to base 10 of the hydrogen (hydronium) ion concentration /  
\[ -\log_{10}[H^+] = -\log_{10}[H_3O^+] = \log_{10}\frac{1}{[H_3O^+]} = \log_{10}\frac{1}{[H^+]} \] (7)

(i) dilute solution (does not work in concentrated solutions) / aqueous solution /  
25 °C (298 K) / 0 – 14 / does not work at extremely low concentrations  ANY TWO: (2 x 3)

(ii) 2.43 / 2.4  
4.5 g /100 cm³ \(\times 10^4\) \(\rightarrow\) 45 g l⁻¹ \(\rightarrow\) 0.75 mol l⁻¹ \(\div 60\) \(\rightarrow\) 0.004166667 mol l⁻¹ \(\rightarrow\) pH = 2.43 / 2.4 (3)

OR  
\[ [H^+]^2 = K_aM \] (1.8 x 10⁻⁵ x 0.75) \(\rightarrow\) \[ [H^+] = \sqrt{K_aM} \] (3) pH = 2.43 / 2.4 (3)

(c) Answer either part A or part B

**A**  
(i) developed x-ray crystallography (x-rays to find crystal structure) (4)  
(ii) used x-rays to find structure of complex molecules (penicillin, vitamin B₁₂ (cobalamin)) \[\{\text{Accept ‘large’, ‘big’, ‘complicated’ for ‘complex’}\}\] (3)

TYPE: covalent molecular (3)

FORCES: Van der Waals’ / London / dispersion / dipole-dipole (3)

EXPLAIN: (i) outer (valence) electrons delocalised / can move easily through the crystal (3)

(ii) attraction of surface ions in crystal for polar water molecules  
overcomes (stronger than) attractions between ions (ion-ion attractions) in crystal / attracts (hydrates, solvates) the ions in the crystal (3)  
\[\text{Can be got from clear diagram showing correct charges}\]

**B**  
(i) blocking (preventing escape, absorption or reabsorption) of radiation (heat, energy, infrared) \(\text{by gases in the atmosphere}\) (4)

(ii) carbon dioxide (CO₂) / methane (CH₄) / chlorofluorocarbon (CFC) / oxides of nitrogen (NOₓ) \(\text{water (H₂O)}\) \[\{\text{Accept ozone}\}\] (3)

(iii) carbon dioxide: fossil fuel combustion / respiration / deforestation / aerosols / car exhausts \(\text{methane: paddy fields (rice growing) / ruminants (cows, sheep, etc., anaerobic digestion) /} \) \(\text{landfill (dumps) / natural gas leakage}\)
chlorofluorocarbon: refrigeration / aerosol propellants / foams / fire extinguishers \(\text{nitrogen oxides: car exhausts / nitrogenous fertilisers}\)
\(\text{water: [Accept fossil fuel combustion / evaporation / transpiration / perspiration (sweating) / excretion/respiration / car exhausts]}\)
\(\text{ozone: [Accept welding /photocopiers]}\) ANY ONE: \[\{\text{Must correspond with answer given in (ii)}\]\(\text{[Accept ozone]}\) (3)

(iv) nitrogen (N₂) / oxygen (O₂) / any identified noble gas (name or formula) (3)

(v) global warming (increase in temperature of Earth) / rise in sea level / melting polar ice / changing climate / drier Summers / wetter Winters / drought / floods / earlier planting / earlier harvesting / lower fertiliser need / increased irrigation / increased plant (animal) diseases / change in crop suitability / extinction of some species / increased carbon dioxide / increased methane / migration of species (birds, etc.) \[\text{ANY THREE: (3 x 3)}\]