Coimisiún na Scrúduithe Stáit
State Examinations Commission

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Ceimic *Ardleibhéal*

Marking Scheme *Leaving Certificate Examination, 2003*

Chemistry *Higher Level*

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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. 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 <u>two</u> questions must be answered from this section]

1. (a) 5; (b) 6 × 3; (c) 6 or 3; (d) 3; (e) (i) 6, (ii) 9, (iii) 3.

2. (a) X 4, Y 4; (b) 3; (c) 6; (d) observation 3, equation 2 × 3; (e) test 3 × 6 [plus equation 3, name 3, subject to the maximum mark for (e) being 18]; (f) 6.

3. (a) 5; (b) diagram 3, mass 4 × 3, volume 3, temperature 3; (c) 6; (d) 12, (e) 6.

Section B

4. <u>Eight</u> 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) (i) 3, (ii) 3; (b) 6; (c) 2 × 3; (d) 2 × 3; (e) 2 × 3; (f) 6; (g) 6; (h) 2 × 3; (i) 2 × 3; (j) 2 × 3; (k) A 2 × 3 or B 2 × 3.

5. (a) (i) 4, (ii) 4, (iii) 3, (iv) 3; (b) electronegativity 2 × 3, (i) 9, (ii) shape 3, angle 3, explain 2 × 3; (b) observe 6, explain 3.

6. (a) which 4, (b) draw 4; (b) X 3, Y 3, Z 3; (c) 3; (d) reagent 3, conditions 3; (e) mechanism 6 × 3, evidence 2 × 3.

7. (a) define 5, (i) 3 × 3, (ii) 3 × 3; (b) catalyst 2 × 3, (i) reactants 3, products 3, environmental benefit 6; (ii) name 3, type 6.

8. (a) (i) 4, (ii) 4, identify 3, 3; (b) pH 6, calculation 12; (c) (i) 6, 3, 3, (ii) 2 × 3.

9. (a) aldehyde 4, IUPAC name 4, other 3, name 3, use 6, which 3, acid 3; (b) (i) 6, (ii) what 2 × 3, describe 6, (iii) 6.

10. (a) define 4, 3; (i) 12; (ii) 6.
(b) graph 3, 3, 6, 6, indicator 3, use 4.
(c) (i) test 4, observation 3, 3; (ii) 5 × 3.

11. (a) state 3, 4; (i) 6; (ii) 12.
(b) (i) 4 or 7; (ii) element *4*: 2 × 3, element *7*: 2 × 3; (iii) 6.
(c) A: formula 4, benefit 3; (i) CFCs 3, use 3; (ii) 4 × 3.
B: (i) 4; (ii) other two 3, 3, forces 3, 2 × 3, use 3, 3.

SECTION A

At least *two* questions must be answered from this section.

QUESTION 1

(a) **prevents oxidation** ('hydrolysis' not acceptable) **by air (atmosphere,** oxygen from the **air) of iron(II) {Fe(II) , Fe^{2+}, iron, Fe} / prevents iron(II) {Fe(II) , Fe^{2+}} going to iron(III) {Fe(III) , Fe^{3+}}** due to **air (atmosphere,** oxygen from the **air)** (5) *Allow only (3) if 'air' is not mentioned.*

(b) tablets **crushed with mortar and pestle //**
washed into beaker //
stirred to dissolve //
transferred into flask using **funnel / glass rod //**
rinsings of beaker **added** to flask //
flask on level surface / mark at eye-level //
add **drop-by-drop /** add **using dropper (pipette, wash bottle) / top up carefully //**
until **bottom of meniscus level with mark //**
invert / mix / shake *["swirl" not acceptable]* ANY SIX: (6 × 3)

(c) to ensure complete **conversion of MnO_4^- {manganate(VII), Mn(VII), Mn^{7+}} to Mn^{2+} {manganese(II), Mn(II)}** / to **fully reduce MnO_4^- {manganate(VII), Mn(VII), Mn^{7+}}** / to **prevent formation of manganese (IV) {Mn(IV), Mn^{4+}, MnO_2, states – which may be specified – other than manganese (II)}** / to **provide sufficient hydrogen ions for complete reduction** (6)
Allow (3) for "to prevent the formation of a brown ppt" or "to allow complete reduction (<u>not</u> oxidation)"

(d) first **permanent pink (purple) / pink (purple) remains / colourless** (*Allow 'pale green'*) **to pink (purple)** (3)

(e) (i) **0.0278 / 0.028** *M* (6)

$$\frac{25 \times X}{5} = \frac{13.9 \times 0.01(0)}{1} \quad (3)$$

$$X = 0.0278 / 0.028 \quad (3)$$

Second (3) not available if (0) obtained for first (3)

(ii) **0.0973 – 0.0982** g (9)
Accept to two significant figures.

$0.0278 \times 56^* = 1.5568 / 1.56 / 1.568 / 1.57$ g l^{-1} (3) [*56 essential] {*55, 57, 65 (– 1)*}

$1.5568 \div 4 = 0.3892 – 0.3925$ g in 250 cm^3 (in four tablets) (3)

$0.3892 \div 4 =$ 0.0973 – 0.0982 g in one tablet (3)

<u>Note</u>: steps may be carried out in a different order.

(iii) **27 %** *(answer that would give 27 if given to two significant figures)* (3)

$$\frac{0.0973^*}{0.36} \times 100 = 27 \quad (3)$$

**Must come from answer in (ii) and give % less than 100*

QUESTION 2

(a) X = **water / hydrogen oxide / H_2O** (4) *Cancelling, including name with formula if either incorrect**

Y = **calcium dicarbide / calcium carbide / carbide / calcium acetylide / CaC_2** (4)
**Cancelling does not apply if name is correct but formula, though incorrect, has Ca and C only.*

(b) **black / dark / grey (off-white) / grey-black / dirty** solid (3)

(c) $CaC_2 + H_2O \longrightarrow C_2H_2 + CaO$ / $CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$ (6)

(d) Observation : **luminous (bright)** flame/**sooty** flame/**dirty** flame/**soot** formed/**carbon** black/**smokey** (3)

Equation: $C_2H_2 + 2½O_2 \longrightarrow 2CO_2 + H_2O$ / $2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O$
FORMULAS (3) BALANCING (3)

(e) Test: **reagent** (6) **procedure** (6) **observation** (6)
[(6) given for procedure even if procedure described is somewhat improbable].

bromine / Br_2 / bromine water (solution) (6)
shake with / mix with / add to / bubble through (6)
decolorised (6) *(dependant on correct test)*

acidified (H^+) (3) manganate(VII) {Mn(VII), MnO_4^-, $KMnO_4$} (3)
shake with / mix with / add to / bubble through (6)
decolorised (6) *(dependant on correct test)*

Note: If the full 18 marks have not been allocated, the following marks can be awarded.
However, remember that the maximum obtainable for part (e) is 18 marks.

equation (3) **name of organic product** (3) [Note: the (6) for reagent may be got from equation]

$C_2H_2 + Br_2 \longrightarrow C_2H_2Br_2$ (3) dibromoethene (3)
$C_2H_2 + 2Br_2 \longrightarrow C_2H_2Br_4$ (3) tetrabromoethane (3)
(substituent numbers not required)

Other correct equations giving products such as bromoethanal, ethanedioic (oxalic) acid etc. For ethanedioic acid the following may be accepted in place of the full equation:

$C_2H_2 + H^+ + MnO_4^- \longrightarrow (COOH)_2$ OR $C_2H_2 \xrightarrow{\text{acidified } MnO_4^-} H_2C_2O_4 / C_2H_2O_4$

(f) **oxyacetylene flame (torch –** *but not blowtorch***) / cutting metals / welding** metals **/making ethanal / making propanone / making propan-2-ol / making polymers (plastics) / pesticides / fuel for lamps** (not 'fuel' on its own) **/ specific* suitable example** (6) **Do not allow general terms e.g.' medicine', 'agriculture', 'industry', 'engineering', but do not treat them as incorrect in a cancelling situation.*

QUESTION 3

(a) **easily changed to gas / easily vaporised / low boiling point** (5)

(b) **diagram** (3) **mass** (4 × 3) **volume** (3) **temperature** (3)

Method 1

diagram: flask, sealed (covered) with foil with small hole (pinhole)* , immersed so that at least half is under water. * *Accept if hole mentioned in account of experiment.* Label required: any one correct label. (3)

mass: get mass of flask and foil (3)
[add liquid and arrange as in diagram]
heat until liquid gone / heat until flask appears empty / vaporised (3)
cool (dry) and reweigh (3)
get mass of sample by subtraction (Get difference) (3)

volume: fill flask and empty into graduated (measuring) cylinder (3) *Accept method using mass & density*

temperature: use thermometer (probe, sensor) to read temperature of water (or got from diagram). (3)
Note: temperature of water or steam cannot be assumed to be 100 °C.

Method 2.

diagram: gas syringe with self-sealing cap (septum cap, can be shown sealed), surrounded by heating device (oven, steam jacket, beaker of water). Label required: any one correct label. (3)

mass: get mass of hypodermic (syringe) containing liquid (3)
inject some liquid into gas syringe (3)
reweigh hypodermic (syringe) (3)
get mass by subtraction (Get difference) (3)

volume: read from gas syringe. (3)

temperature: read from thermometer (probe, sensor) in heating device (or got from diagram). (3)
Note: temperature of water or steam cannot be assumed to be 100 °C.

(c) **barometer / bourdon guage / barograph (barothermograph) / pressure sensor (not probe)** (6)
"pressure gauge" not acceptable.

(d) **0.0031 / 0.00309** mol (12)

$T = 97 + 273 = 370$ (3)

$V = 95 \times 10^{-6}\ m^3 / 0.000095\ m^3$ (3)

$n = \frac{PV}{RT} = \frac{1 \times 10^5 \times 95 \times 10^{-6}}{8.3 \times 370}$ (3)

$= 0.00309 / 0.0031$ (3)

$T = 97 + 273 = 370$ (3)

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow \frac{1 \times 10^5 \times 95}{370} = \frac{1.013\ (\text{or } 1) \times 10^5 \times V_2}{273}$ (3)

$V_2 = 69.2 / 69.19\ (\text{or } 70.1 / 70.09)\ cm^3$ (3)

$\frac{69.2 / 69.19\ (\text{or } 70.1 / 70.09)}{22400} = 0.00309 / 0.00313 / 0.0031$ (3)

(e) M_r = **89** [or any answer that gives 87.5 – 90] (6)

$M_r = \frac{0.275^*}{0.0031}$ (3) = 89 (3)

**If this fraction is incorrect, both (3)s are lost. If clear that an error was made in taking down 0.275 from paper (e.g. 0.27), treat as slip (–1).*

SECTION B

QUESTION 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) (i) **18** electrons (3) (ii) **20** neutrons (3)

(b) **6.6 x 10^{23}** electrons (6)

$2.3 \div 23 = 0.1$ mol (3) $0.1 \times 6 \times 10^{23} = 6 \times 10^{22}$ atoms

6×10^{22} x 11 = 6.6×10^{23} electrons (3)

(c) **pressure inversely proportional to volume / $PV = k$** (3) **for definite mass** of gas **at constant temp** (3)

(d) positive **ions (charged particles) separated (deflected) by mass** (3) when **moving in a magnetic field** (3)

(e) **oxidation / breakdown / use of air (oxygen)** (3) (*Accept 'anaerobic digestion'*)
by micro-organisms (bacteria) / biological / chemical / activated sludge (3)

(f) **alpha, beta, gamma** / **alpha beta gamma** / **gamma beta alpha** ↑ **/ clear correct description of order of penetration** (6)

(g) **35** % (6)

formula mass = 80 mass of nitrogen = 28 $\frac{28 \times 100}{80}$ (3) = 35 (3)

(h) **structure** (3) **name** (3)
(structure & name must be matched)

$HCOOC_2H_5$ / C_2H_5OOCH (3) ethyl methanoate (ethyl formate) (3)
CH_3COOCH_3 / CH_3OOCCH_3 (3) methyl ethanoate (methyl acetate) (3)
In expanded structures, correct bonds must be shown but Hs can be omitted.

(i) Mendeleev {Moseley}*: **order of atomic mass (weight) {order of atomic number} / gaps (fewer elements) {fewer gaps (no gaps), more elements } / reversed elements {no reversing} / man-made elements absent {man-made elements present} / transition elements not in separate block {transition elements in separate block} / lanthanides (rare earths) not in separate block {lanthanides in separate block} / actinides not in separate block {actinides in separate block} / no detectable naturally-occurring radioactive elements {detectable naturally-occurring radioactive elements present}** *[Accept: noble gases absent {noble gases present}]*
Note: the differences may be given from either point of view. ANY TWO: (2 × 3)

**If Mendeleev right but Moseley wrong (or vice versa) for same point, the (3) not given.*

(j) **Oxygenates* (*MTBE*, methanol, ethanol) / branches / short chains / rings (or ring hydrocarbon) / isomerisation / reforming / dehydrocyclisation / cracking** ANY TWO: (2 × 3)
* *Not "oxygenation".* *Cancelling applies here but not in the case of lead.*

(k) A. $N_2 + O_2 \longrightarrow 2NO$ / $\frac{1}{2}N_2 + \frac{1}{2}O_2 \longrightarrow NO$ FORMULAS: (3) BALANCING: (3)

B. **variable valency / coloured ions (compounds) / act as catalysts / compounds act as catalysts**
ANY TWO: (2 × 3)

QUESTION 5

(a) (i) **discrete (fixed, restricted) energy of electron / energy of electron in orbital / shell (orbit) which electrons of equal energy can occupy** (4)

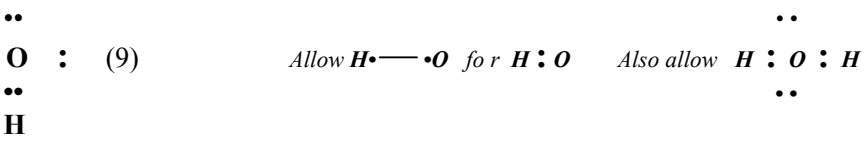
(ii) **high probability region for electron / region in which electron is likely to be found** (4)

(iii) $1s^2 2s^2 2p^3$ / $1s^2 2s^2 2p_x^1 2p_y^1 2p_z^1$ * (3)

(iv) **one electron in each of the three p orbitals /** $2p_x^1 2p_y^1 2p_z^1$ /  (3) *Can be got from orbital diagram if single occupancy clear.*

$*1s^2 2s^2 2p_x^1 2p_y^1 2p_z^1$ can get the marks for (iii) and (iv) *Do not accept* $2p_x^1 y^1 z^1$ *in (iii) or (iv)*

(b) Electronegativity: **relative (measure of) attraction / number expressing (giving) attraction** (3)
for shared electrons / for electrons in a covalent bond (3)

(i)  (9) *Allow* H•—•O *for* H:O *Also allow* H:O:H

(Correct shell diagrams perfectly acceptable. All dots acceptable for dots and crosses)

(ii) Shape: **v-shaped / bent** (3)

Angle: **104°** (3)

Explain: **greater repulsion by lone pairs / l.p.– l.p. > etc.** (3)

pushes bonds closer together / reduces (lowers) bond angle (3)

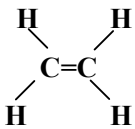
(c) Observe: **water attracted to rod** (6) *Allow (3) for "deflected"*

Explain: **water is polar** (3)

Allow "water has (is) a dipole" or correct dipole diagram (non-linear with charges)

QUESTION 6

(a) Which: **A / C_2H_4 / ethene / ethylene** (4)

Draw:  **/ $H_2C=CH_2$ / $CH_2=CH_2$** (4)

(In expanded structure, correct bonds must be shown but Hs can be omitted.)

(b) X = **addition** (3)

Y = **addition** (3)

Z = **substitution** (3)

(c) **hydrogen chloride / $HCl_{(g)}$** (3) *Do not allow 'hydrochloric acid'. If 'hydrochloric acid, HCl' given, cancelling applies.*

(d) Reagent: **chlorine / dichlorine / Cl_2** (3)

Conditions: **ultraviolet (uv)** light (3) *"sunlight" not acceptable*

(e) Mechanism: **repulsion by double bond /polarised** HCl **bond / Side-on approach** (3)
splits HCl into ions / heterolytic fission of HCl / HCl $\longrightarrow$ **H^+ + Cl^-** (3)
H^+ uses pi **electrons of double bond to bond with one carbon atom** (3)
leaving other carbon positively charged / forming carbonium ion (carbocation) (3)
Cl^- approaches / attacks / bonds (3)
with C^+* (carbonium ion, carbocation) (3) **To get marks for C^+, the positive charge must be shown on the carbon atom, not on the whole formula.*
(Allow only the last three points for Cl_2 mechanism)

Note: all points can be got from suitable diagrams.

Evidence: **addition using bromine water** (3)

gives 2-bromoethanol (CH_2BrCH_2OH) (3)

OR

addition with bromine water containing a chloride (sodium chloride) (3)

gives 1-bromo-2-chloroethane *(Allow 1-chloro-2-bromoethane)* **(CH_2BrCH_2Cl)** (3)

OR

Another specified anion / chlorine water / HCl in water ($HCl_{(aq)}$, hydrochloric acid) (3)

Product where that anion has added in place of the chlorine (e.g. 2-chloroethanol for chlorine water, and ethanol for $HCl_{(aq)}$)

Correct name cancels with incorrect formula and vice versa. For a correct name, numbers must be present if they are necessary to avoid ambiguity regarding the positions of substituents. However, an ambiguous name does not cancel with a correct formula.

QUESTION 7

(a) Define: **change in concentration per unit time / $\frac{\text{change in concentration}}{\text{time}}$** (5)

Accept 'rate of change of concentration'.

Do not accept 'mass', 'volume', 'quantity', 'amount' in place of 'concentration'.

(i) mass of **small particles (powder),** equal mass of **larger particles (granules, lumps)** (3)
added to equal volumes of HCl (acid) of same concentration (3)
note times to complete reactions / observe vigour of reactions / smaller particles faster (3)
(Can be got from clear graph)

(ii) **equal masses (amount) of equal-sized particles (e.g. powder*)** of $CaCO_3$ (3)
added to equal volumes of HCl (acid) of different concentrations (3)
note times to complete reactions / observe vigour of reactions / higher conc. faster (3)
** "Equal-sized" needed for all particles except powder.* *(Can be got from clear graph)*

(b) Catalyst: **substance that alters (speeds up) rate of reaction** (3)

not consumed (not used *up*) / chemically unchanged *at the end* (3)

(i) **reactant(s)** (3) **product(s)** (3) **environmental benefit*** (6)

*Note: the environmental benefit must be a primary effect [e.g. toxicity (CO), smog prevention (hydrocarbons), acid rain (NO_x)], or a specific and valid secondary effect [e.g. respiratory problems (hydrocarbons), killing of fish (NO_x)]. General statements such as 'prevents pollution' or 'harmful gases' are not sufficient. However, allow 'prevents air pollution' in all four cases for (3) marks.

carbon monoxide (3) carbon dioxide (3) CO toxic (6)

hydrocarbons (3) carbon dioxide & water (3) prevents smog / reduces greenhouse effect (6)

CO and NO (3) CO_2 and nitrogen (3) CO toxic / NO leads to acid rain (6)

nitrogen oxides (3) nitrogen and oxygen (3) NO_x cause acid rain (6)
(or specified NO_x)

Note: reactant and product marks can be got from equations which need not be balanced.

(ii) Name: **platinum / palladium / rhodium** ANY ONE: (3) *Accept symbols. Do not accept 'gold'.*

Type: **heterogeneous / adsorption** (6)

QUESTION 8

(a) (i) **proton donor / donor of hydrogen ions (H^+)** (4)

(ii) **proton acceptor / acceptor of hydrogen ions (H^+)** (4)

Identify: **H_2S** (3) **OH^-** (3) *Note: both are acids; both are also conjugate acids. Therefore, the order does not matter.*

(b) pH = **$-\log_{10}[H^+]$ / $-\log_{10}[H_3O^+]$ / negative log** to base ten **of hydrogen (hydronium) ion concentration** (6)

Calc: pH = **2.37 – 2.4** (12)

6 % (w/v) = 6 g in 100 cm^3 = 60 g l^{-1} (3)
60 g l^{-1} ÷ 60 = 1 mol l^{-1} (3)
$[H^+]^2 = 1.8 \times 10^{-5}$ / $[H^+] = \sqrt{1.8 \times 10^{-5}}$ / 0.0042 (3)
pH = $-\log [H^+] = -\log\sqrt{1.8 \times 10^{-5}} = 2.37 - 2.4$ (3)

OR

6 % (w/v) = 6 g in 100 cm^3 = 60 g l^{-1} (3)
60 g l^{-1} ÷ 60 = 1 mol l^{-1} (3)
pH = $-\log \sqrt{K_a \times M}$ / $-\log \sqrt{1.8 \times 10^{-5} \times 1}$ (3)
$= -\log\sqrt{1.8 \times 10^{-5}} = 2.37 - 2.4$ (3)

For second (3) use the number coming from the first point even if that number is 6. However, division by a number other than 60 loses this (3) unless there is clear evidence of a slip.

As above.

(c) (i) **absorbance / intensity (depth) of colour** (6)
is proportional / ∝ (other answers must clearly mean 'proportional') (3)
to concentration / amount (3)

(ii) chlorine **present as chloric(I) acid (hypochlorous acid, HOCl, HClO) / and chlorate(I) ions (hypochlorite ions, OCl^-, ClO^-) / chlorine (dichlorine, Cl_2)** Any two: (2 × 3)

OR

chlorine /dichlorine / Cl_2 (3)
available as oxidising agent (3)

QUESTION 9

(a) Aldehyde: **CH_3CH_2CHO / C_2H_5CHO** (4)
(In expanded structure, correct bonds must be shown but Hs can be omitted.)

IUPAC: **propanal** (4) *[Accept propan-1-al]*

Other: **CH_3COCH_3** (3)

Name: **propanone / acetone** (3) *[Accept propan-2-one]*
(In expanded structure, correct bonds must be shown but Hs can be omitted.)

Use: **removing nail varnish / cleaning glassware / solvent for (used in) paints (lacquers, varnishes) / chromatography / recrystallisation / solvent extraction / solvent for nitrocellulose / dry cleaning / stain (grease) removing / industrial solvent (not 'solvent' or 'organic solvent')** (6)

Which: **propanal** (3) *[Accept propan-1-al]* *If name at IUPAC above is wrong, no marks are given for repeating it here. If the candidate simply writes 'the aldehyde', this is acceptable provided the aldehyde was correctly identified at IUPAC above.*

Acid: **propanoic acid / propionic acid** (3) *Given independently of answer to 'Which' above.*

(b) (i) **releases pressure / prevents explosions / allows expansion / releases steam (**hot **water)** (6)
Allow (3) for 'safety'. [Note: 'safety' with one of the (6) mark answers does not involve cancelling.]

(ii) What: mixture of **clove oil** *[Accept eugenol]* (3) and **water** (3)

Describe: **cloudy* / milky** *(not 'creamy')* **/ white / emulsion** (6)
**Allow only (3) if 'cloudy' given with anything other than 'milky', 'white' or 'emulsion' e.g. allow only (3) for 'cloudy green', 'cloudy grey' etc.*

(iii) **flavouring / seasoning / spice / used in food / medicines / dental preparations (dentistry) / sweets / perfume / making vanillin / source of eugenol / antiseptic / disinfectant /** local **anaesthetic / aromatherapy** (6) *[Allow 'cigarettes' and 'soap'.]*

QUESTION 10: Answer *two* of the parts (a), (b) and (c). **(2 × 25)**

(a) Define: heat when **1 mole** (4) is **burned completely / burned in excess oxygen** (3)

(i) Calc: ΔH = **– 2222** kJ mol^{-1} (12)

$3C + 4H_2 \longrightarrow C_3H_8$ ΔH = – 104 kJ mol^{-1}
$C + O_2 \longrightarrow CO_2$ ΔH = – 394 kJ mol^{-1}
$H_2 + ½O_2 \longrightarrow H_2O$ ΔH = – 286 kJ mol^{-1}

$C_3H_8 \longrightarrow 3C + 4H_2$ ΔH = **104** kJ mol^{-1} (3)
$3C + 3O_2 \longrightarrow 3CO_2$ ΔH = **3 x – 394 / – 1182** kJ mol^{-1} (3)
$4H_2 + 2O_2 \longrightarrow 4H_2O$ ΔH = **4 x – 286 / – 1144** kJ mol^{-1} (3)
$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$ ΔH = **– 2222** kJ mol^{-1} (3)

Equations *not* required

OR

$\Sigma \Delta H_{formation}$(products) – $\Sigma \Delta H_{formation}$(reactants) = ΔH

3 × – 394 / – 1182 (3) **4 × – 286 / – 1144** (3) **– (–104) / + 104 / 104** (3) = **– 2222** kJ mol^{-1} (3)

(ii) **10** g (6) $\frac{1}{2222} \times 500 = 0.225$ mol (3) × 44 = 10 (3) OR $\frac{44}{2222} \times 500$ (3) = 10 (3)

Note: penalty (– 1) if answer not rounded off to 10.

(b) Graph: **axes correct and correctly labelled** (*pH axis does not have to start at 0*) (3, 3)
[Note: penalty (–3) if pH on horizontal axis and volume on vertical axis.]
all points correctly plotted (6) {*Allow (3) for 8 points plotted correctly*} {*not on graph paper (– 6)*}
correct graph line (*based on their points – no penalty for not joining the first or the last pair of points*) (6)

Indicator: **bromothymol blue / phenol red / neutral red / cresol purple / thymol blue / phenolphthalein / thymolphthalein** (3)

Use: **range of indicator (indicator colour change) within pH jump on graph** *(unambiguously identified e.g 'within vertical part of graph' or 'between lower and upper pH values of vertical part of their graph' or 'between values from table (6 – 11 or 6 – 11.2) corresponding to vertical part of graph' or 'any range (e.g. 8 – 10) within the vertical part of the graph'.* (4) {*Note: this (4) can be given even if the indicator chosen is incorrect.*}

(c) (i) Test: **flame** test **/ atomic absorption spectrometry (AAS)** (4)

Obs: flame test: sodium: **yellow / orange** (*Accept 'amber'*) (3) potassium: **lilac / violet** (***not 'purple'***) (3)
OR AAS: sodium: **yellow /orange** (*Accept 'amber'*) / characteristic **absorption spectrum of sodium** (3)
potassium: **lilac / violet** (***not 'purple'***) / characteristic **absorption spectrum of potassium** (3)

(ii) add **barium chloride {$BaCl_2$} / barium nitrate {$Ba(NO_3)_2$}** soln / soluble source of **barium ions (Ba^{2+})** (3)
white precipitate with both sulfite and sulfate (3) *[linked to first (3) – not given if reagent incorrect]*
add dilute **hydrochloric acid {HCl}** (3) *[Last three (3)s can be given even if first (3) not got.]*
precipitate dissolves indicating sulfite (3) / *Note: if barium reagent & HCl are added at*
precipitate remains (does not dissolve) indicates sulfate (3) *the same time, the second (3) is not available.*
[Note: if either one of the last two points is given, the other can be inferred]
(maximum = 12)

QUESTION 11: Answer any *two* of the parts (a), (b) and (c). **(2 × 25)**

(a) State: reactions at **equilibrium** (3) **oppose** (*Accept 'minimise', 'relieve'*) **applied stresses*** (4)
**If the word stress(es) is replaced by particular examples (e.g. pressure), all three (temp., pressure & conc.) must be given.*

(i) $\dfrac{[HI]^2}{[H_2][I_2]}$ (6)

(ii) **1.56** mol (12) *Allow calculations based on:* $H_2 + I_2 \rightleftharpoons 2HI$ (1 mol, 1 mol, 0 mol)

$H_2 + I_2 \rightleftharpoons 2HI$ 0 mol 0 mol 2 mol $(2-x)/2$ $(2-x)/2$ x (3) $\dfrac{x^2}{\{(2-x)/2\}^2} = 50$ (3) $\dfrac{x}{(2-x)/2} = 7.07\ (7.1)$ (3) $x = [HI] = 1.56$ (3)	$H_2 + I_2 \rightleftharpoons 2HI$ 0 mol 0 mol 2 mol $(2-x)/2$ $(2-x)/2$ x (3) $\dfrac{x^2}{\{(2-x)/2\}^2} = 50$ (3) $46x^2 - 200x + 200 = 0\ /\ 23x^2 - 100x + 100 = 0$ (3) $x = [HI] = 1.56$ (3)

$H_2 + I_2 \rightleftharpoons 2HI$ 0 mol 0 mol 2 mol x x $2-2x$ (3) $\dfrac{(2-2x)^2}{x^2} = 50$ (3) $\dfrac{2-2x}{x} = 7.07\ /\ 7.1$ (3) $x = 0.22 \Rightarrow [HI] = 1.56$ (3)	$H_2 + I_2 \rightleftharpoons 2HI$ 0 mol 0 mol 2 mol x x $2-2x$ (3) $\dfrac{(2-2x)^2}{x^2} = 50$ (3) $46x^2 + 8x - 4 = 0\ /\ 23x^2 + 4x - 2 = 0$ (3) $x = 0.22 \Rightarrow [HI] = 1.56$ (3)

$H_2 + I_2 \rightleftharpoons 2HI$ 0 mol 0 mol 2 mol $\frac{1}{2}x$ $\frac{1}{2}x$ $2-x$ (3) $\dfrac{(2-x)^2}{(\frac{1}{2}x)^2} = 50$ (3) $\dfrac{2-x}{\frac{1}{2}x} = 7.07\ /\ 7.1$ (3) $x = 0.44 \Rightarrow [HI] = 1.56$ (3)	$H_2 + I_2 \rightleftharpoons 2HI$ 0 mol 0 mol 2 mol $\frac{1}{2}x$ $\frac{1}{2}x$ $2-x$ (3) $\dfrac{(2-x)^2}{(\frac{1}{2}x)^2} = 50$ (3) $46x^2 + 16x - 16 = 0\ /\ 23x^2 + 8x - 8 = 0$ (3) $x = 0.44 \Rightarrow [HI] = 1.56$ (3)

$H_2 + I_2 \rightleftharpoons 2HI$ 0 mol 0 mol 2 mol $1-x$ $1-x$ $2x$ (3) $\frac{(2x)^2}{(1-x)^2} = 50$ (3) $\frac{2x}{1-x} = 7.07 / 7.1$ (3) $x = 0.78 \Rightarrow [HI] = 1.56$ (3)	$H_2 + I_2 \rightleftharpoons 2HI$ 0 mol 0 mol 2 mol $1-x$ $1-x$ $2x$ (3) $\frac{(2x)^2}{(1-x)^2} = 50$ (3) $46x^2 - 100x + 50 = 0 / 23x^2 - 50x + 25 = 0$ (3) $x = 0.78 \Rightarrow [HI] = 1.56$ (3)

(b) (i) **increase in nuclear charge / increasing atomic no. / increasing no of protons**
decrease in atomic radius one correct (4) both correct (7)

(ii) Element 4: **outer sublevel (subshell, orbital) full / all sublevels (subshells) full /** ***1s²2s²*** / **electron from full *2s* sublevel (subshell, orbital)** (3)
giving increased **stability*** (3)

Element 7: **half-full *p* sublevel (subshell) /** ***1s²2s²2p³*** / ***1s²2s²2p$_x^1$2p$_y^1$2p$_z^1$*** (3)
giving increased **stability*** (3) **For <u>one</u> incorrect use of 'orbital' in answering the stability points (–3)*

(iii) **electron removed from monopositive ion (atom) / $X^+ \rightarrow X^{2+} + e^- / X^+ - e^- \rightarrow X^{2+}$** (6)
Accept 'from positive ion (atom)' for (3). *Allow symbol of any element in place of X*
e.g. $Na^+ \rightarrow Na^{2+} + e^-$.

(c) A Formula: **O_3** (4)
Benefit: **blocks solar uv /** helps **prevent skin cancer / blocks harmful solar rays** (3)

(i) CFCs **chlorofluorocarbons / compound of C,F & Cl only / alkane fully substituted with F & Cl** (3)
Use: **refrigerants (fridges) / air-conditioning / fire extinguishers /** expanded **polystyrene /**
propellant <u>gas</u> in something specified (e.g. aerosols, deodorants, etc.) *('gas' essential)* (3)

(ii) **release chlorine free radicals {$Cl^\bullet$,chlorine atoms** *(but not Cl)*} (3)
these {the chlorine free **radicals ($Cl^\bullet$)** – not the CFCs} **attack ozone / $O_3 + Cl^\bullet = ClO^\bullet + O_2$** (3)
reaction with oxygen free radicals ($O^\bullet$) / chain reaction (3)
regenerating chlorine free radicals {$Cl^\bullet$, chlorine atoms *(but not Cl)*} **/ releasing chlorine free radicals {$Cl^\bullet$, chlorine atoms** *(but not Cl)*} **again** (3) *Accept 'producing (giving, giving more, releasing) $Cl^\bullet$'*
[Note: $ClO^\bullet + O^\bullet = Cl^\bullet + O_2$ gets last two (3)s] *<u>Note</u>: dots on radicals <u>not</u> required <u>except in the case if the first (3)</u>*

B (i) **carbon / C** (4)

(ii) Other two: **diamond** (3) **graphite** (3)
Forces: diamond: **covalent bonds** (3) | graphite: **covalent in layers** (3)
van der Waals (London, dispersion) between layers (3)
<u>Note</u>: if neither of these two (3)s is got, one (3) can be given for 'covalent and van der Waals (London, dispersion)'

Use: diamond: **cutting / drilling / gem (jewel, ring)** (3)
graphite: **lubricant / pencils / paints / carbon fibres / sports equipment (golf clubs, etc.) /**
steel / electrodes / batteries / nuclear reactors (3)