Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2017

Marking Scheme

Chemistry

Higher Level

Note to teachers and students on the use of published marking schemes

Marking schemes published by the State Examinations Commission are not intended to be standalone documents. They are an essential resource for examiners who receive training in the correct interpretation and application of the scheme. This training involves, among other things, marking samples of student work and discussing the marks awarded, so as to clarify the correct application of the scheme. The work of examiners is subsequently monitored by Advising Examiners to ensure consistent and accurate application of the marking scheme. This process is overseen by the Chief Examiner, usually assisted by a Chief Advising Examiner. The Chief Examiner is the final authority regarding whether or not the marking scheme has been correctly applied to any piece of candidate work.

Marking schemes are working documents. While a draft marking scheme is prepared in advance of the examination, the scheme is not finalised until examiners have applied it to candidates' work and the feedback from all examiners has been collated and considered in light of the full range of responses of candidates, the overall level of difficulty of the examination and the need to maintain consistency in standards from year to year. This published document contains the finalised scheme, as it was applied to all candidates' work.

In the case of marking schemes that include model solutions or answers, it should be noted that these are not intended to be exhaustive. Variations and alternatives may also be acceptable. Examiners must consider all answers on their merits, and will have consulted with their Advising Examiners when in doubt.

Future Marking Schemes

Assumptions about future marking schemes on the basis of past schemes should be avoided. While the underlying assessment principles remain the same, the details of the marking of a particular type of question may change in the context of the contribution of that question to the overall examination in a given year. The Chief Examiner in any given year has the responsibility to determine how best to ensure the fair and accurate assessment of candidates' work and to ensure consistency in the standard of the assessment from year to year. Accordingly, aspects of the structure, detail and application of the marking scheme for a particular examination are subject to change from one year to the next without notice.

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. A double solidus (//) separates points for which separate marks are allocated in a part of the question. Words, expressions or statements separated by a solidus (/) are alternatives which are equally acceptable for a particular point. 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 incorrect use of terminology or contradiction, the marks may not be awarded. Cancellation may apply when a candidate gives a list of correct and incorrect answers.

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. This deduction applies to incorrect M_r values but only if a candidate shows the addition of all the correct atomic masses and the error is clearly an addition error. If the addition of atomic masses is not shown, the candidate loses 3 marks for an incorrect M_r.

7. Bonus marks at the rate of 10% of the marks obtained will be given to a candidate who answers entirely through Irish and who obtains less than 75% of the total marks. In calculating the bonus to be applied decimals are always rounded down, not up e.g., 4.5 becomes 4; 4.9 becomes 4, etc. The bonus table given on the next page applies to candidates who answer entirely through Irish and who obtained more than 75% of the total marks.

Candidates are required to answer eight questions in all.

These must include at least two questions from Section A.

All questions carry equal marks (50).

Marcanna Breise as ucht freagairt trí Ghaeilge

Léiríonn an tábla thíos an méid marcanna breise ba chóir a bhronnadh ar iarrthóirí a ghnóthaíonn níos mó ná 75% d'iomlán na marcanna.

N.B. Ba chóir marcanna de réir an ghnáthráta a bhronnadh ar iarrthóirí nach ngnóthaíonn níos mó ná 75% d'iomlán na marcanna don scrúdú. Ba chóir freisin an marc bónais sin **a shlánú síos**.

Tábla 400 @ 10%

Bain úsáid as an tábla seo i gcás na n-ábhar a bhfuil 400 marc san iomlán ag gabháil leo agus inarb é 10% gnáthráta an bhónais.

Bain úsáid as an ngnáthráta i gcás 300 marc agus faoina bhun sin. Os cionn an mharc sin, féach an tábla thíos.

Bunmharc	Marc Bónais	Bunmharc	Marc Bónais
301 - 303	29	351 - 353	14
304 - 306	28	354 - 356	13
307 - 310	27	357 - 360	12
311 - 313	26	361 - 363	11
314 - 316	25	364 - 366	10
317 - 320	24	367 - 370	9
321 - 323	23	371 - 373	8
324 - 326	22	374 - 376	7
327 - 330	21	377 - 380	6
331 - 333	20	381 - 383	5
334 - 336	19	384 - 386	4
337 - 340	18	387 - 390	3
341 - 343	17	391 - 393	2
344 - 346	16	394 - 396	1
347 - 350	15	397 - 400	0

QUESTION 1

(*a*) (*i*) EXPLAIN: solution of **known concentration (molarity)** **(5)**

    (*ii*) GIVE: **pure //** water **soluble // solid // high molecular mass // stable** in air {**not oxidised by air, does not effloresce (lose water of crystallisation), does not deliquesce (absorb water from air), is not hygroscopic} //** mass true (accurate) **representation of number of moles present //** anhydrous (not hydrated, does not have water of crystallisation)

ANY TWO: (2×3)

[Allow **one** of either '*non-toxic*' or '*cheap*' or '*readily available*' for 3 if no other marks awarded]

[Allow 3 marks for **enables** accurately **known concentration to be obtained** if no other marks awarded]

(*b*) EXPLAIN: (*i*)   **to prevent** air **oxidation** of the Fe^{2+} in solution / **to prevent** Fe^{2+} in solution **reacting with** dissolved **oxygen (air) / to avoid formation of Fe^{3+} / to stabilize Fe^{2+}**   **(3)**

[Allow '*to prevent hydrolysis of Fe^{2+}*' and '*to prevent Fe^{2+} reacting with water*'.]

EXPLAIN: (*ii*)   to ensure **MnO_4^- {Mn(VII)} reduced to (produces, forms)** colourless **Mn^{2+} {Mn(II)} / to prevent** formation **of MnO_2 {Mn(IV), brown** precipitate**}** in solution   **(6)**

[Allow **Mn^{7+} for Mn(VII)** and **Mn^{4+} for Mn(IV)**.]

[Allow **MnO_4^- {Mn(VII), Mn^{7+}, MnO_2, Mn(IV), brown** precipitate**}** '**fully reduced**' or '**to ensure reaction goes to completion**'.]

[Allow 3 marks only for *oxidation* of **MnO_4^- {Mn(VII), Mn^{7+}, MnO_2, Mn(IV)} to Mn^{2+} {Mn(II)}**.]

(*c*) DESCRIBE PROCEDURE: **swirl flask** while adding manganate(VII) (solution from burette) **//**
rinse down inside **walls (sides, inside) of flask (container, vessel) with deionised (distilled, pure) water** at intervals **//**
add manganate(VII) **dropwise (slowly) as end point is approached //**
read burette at eye-level //
keep burette vertical //
read top of meniscus //
carry out a rough titration //
repeat to **find two** or more **titres (readings) that agree to** within **0.1 cm³ //**
use a white tile (surface, paper) to see colour changes in flask clearly

ANY FOUR: (4×3)

[Allow '*beaker*' for '*flask*'.]

WHAT OBS: faint (pale) **pink** colour remains   **(3)**
['*Pink to colourless*' not acceptable.]

(*d*)   CALCULATE: (*i*)   **0.00225 (2.25 × 10⁻³)** moles   (6)

$$M = \frac{8.82 \times 4}{392^*} = \textbf{0.09}^{**} \text{ M} \qquad (3)$$

$$\frac{25 \times 0.09}{1000} = \textbf{0.00225 (2.25} \times \textbf{10}^{-3}) \text{ moles} \qquad (3)$$

/

$$\frac{8.82}{10} = \textbf{0.882} \text{ g in 25 cm}^3 \qquad (3)$$

$$\frac{0.882}{392^*} = \textbf{0.00225 (2.25} \times \textbf{10}^{-3}) \text{ moles} \qquad (3)$$

/

$$\frac{8.82}{392^*} = \textbf{0.0225 (2.25} \times \textbf{10}^{-2}) \text{ moles in 250 cm}^3 \qquad (3)$$

$$\frac{0.0225}{10} = \textbf{0.00225 (2.25} \times \textbf{10}^{-3}) \text{ moles} \qquad (3)$$

/

$$\frac{56 \times 100}{392^*} = 14.29\%, \ 14.29\% \text{ of } 8.82 = 1.26 \text{ g}$$

$$M = \frac{1.26 \times 4}{56} = \textbf{0.09}^{**} \text{ M} \ / \ \frac{1.26}{56} = \textbf{0.0225 (2.25} \times \textbf{10}^{-2}) \text{ moles in 250 cm}^3 \qquad (3)$$

$$\frac{25 \times 0.09}{1000} \ / \ \frac{0.0225}{10} = \textbf{0.00225 (2.25} \times \textbf{10}^{-3}) \text{ moles} \qquad (3)$$

[*Addition must be shown for error to be treated as slip.]
[**Only figure to be used as molarity in (*d*) (*iii*)]

   (*ii*)   **0.00045 (4.5 × 10⁻⁴)** moles   (3)

0.00225 ÷ 5 **= 0.00045 (4.5 × 10⁻⁴)** moles   (3)

   (*iii*)   **0.022** M   (6)

$$\frac{0.00045}{20.45} = 0.0000220 = \textbf{0.000022} \text{ moles / cm}^3 \qquad (3)$$

0.0000220 × 1000 = 0.0220 = **0.022** M   (3)

/

$$\frac{20.45 \times M}{1} = \frac{25 \times 0.09^{**}}{5} \qquad (3)$$

$$M = 0.0220 = \textbf{0.022} \text{ M} \qquad (3)$$

[1 mark to be deducted for incorrect rounding off resulting in candidate's final numerical answer lying outside given value but deduction to be made once only in (*d*).]

QUESTION 2

(*a*) (*i*) WHAT: reaction mixture turns **milky (white) / bubbling / vapour (steam, smoke) / effervescence (fizzing) / solid (CaC₂, calcium** di**carbide) reacts / flask gets hot**   (3)

   (*ii*) EXPLAIN: contain **air (nitrogen, oxygen, argon, carbon dioxide)**   (3)
   [Allow impure.]

(*b*) (*i*) DRAW: **heat applied to aluminium oxide (alumina, Al₂O₃) // ethanol (C₂H₅OH)**   (2 × 3)

            glass wool (fibre glass, cotton wool) holding ethanol // at end of horizontal test tube // gas collected over water / gas collected in gas syringe (balloon, etc)   ANY TWO: (2 × 3)

            [Where no diagram or arrangement incorrect, award maximum (9) marks.]
            [Accept '*steel wool*' instead of '*fibre glass*'.]
            [Accept liquid shown in collecting trough, and unlabelled, as water.]
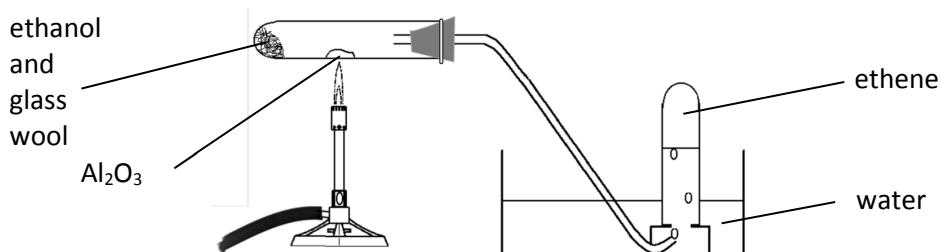
   (*ii*) STATE AND EXPLAIN: ANY TWO STATED PRECAUTIONS: (2 × 3)
                                  ANY TWO LINKED EXPLANATIONS: (2 × 3)

State Precaution	ANY TWO: (2 × 3)	Explain Precaution	ANY TWO: (2 × 3)
remove delivery **tube from water (loosen** test-tube **stopper) before removing heat** at end	(3)	**avoid suckback** into hot test-tube**/ avoid flying glass (chemical splash) / avoid test-tube (apparatus) cracking**	(3)
keep ethanol (ethene, stopper) away from flame / keep test-tube **stopper tightly fitted**	(3)	**ethanol (ethene, stopper) flammable /avoid fumes from burning stopper**	(3)
use Pyrex (boiling, stout-walled) test-tube / apply heat to test-tube gently before heating strongly / avoid prolonged heating of test-tube at the same place	(3)	**avoid test-tube cracking / avoid fire (burns)**	(3)
keep long **hair tied back**	(3)	**avoid burns (contact with chemical**s**)**	(3)
wear eye-protection (goggles) / use safety screen) /	(3)	**avoid burns (cuts from flying glass, contact with chemical**s**)**	(3)
wear gloves / use tongs (forceps) / do not touch glass wool	(3)	**avoid burns (cuts from flying glass, contact with chemical**s**)**	(3)
wear mask (lab coat)	(3)	**avoid contact with chemical**s	(3)

[Correct, linked, specific, chemical hazard, e.g. '*glass wool irritating*' acceptable.]

(*c*)   (*i*)   COMPARE: comparison:

         ethyne flame **smokier (sootier, brighter, more luminous, yellower)** than ethene's **/**
         ethene flame **cleaner** (**not as bright, less luminous, bluer**) than ethyne's **/**

         statement:
         ethyne smoky (sooty, yellow, bright) / ethene clean (blue, bluish, yellowish)   (3)

   (*ii*)   WRITE: $C_2H_2 + 2\frac{1}{2}\,O_2 \rightarrow 2CO_2 + H_2O$ / $2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

                                                       FORMULAE: (3) BALANCING: (3)

(*d*)   NAME: **bromine (Br_2)** solution (water) / **acidified** potassium **manganate(VII) {permanganate} /**
         ($KMnO_4/H^+$) / (MnO_4^-/H^+)   (3)

(*e*)   CALCULATE: $\mathbf{3.0 \times 10^{22}}$ molecules   (8)

$\dfrac{3.2}{64^*}$ = **0.05** moles calcium carbide   (3)

$\Rightarrow$ **0.05** moles ethyne / **1:1** CaC_2:ethyne   (3)

$0.05 \times 6.0 \times 10^{23} = \mathbf{3.0 \times 10^{22}}$ molecules   **(2)**

[*Addition must be shown for error to be treated as slip.]

QUESTION 3

(*a*) DEFINE: **change in concentration per unit time / rate of change of concentration /**
$$\frac{change\ in\ concentration}{time}$$
(3)

of **one (a) reactant (product)** **(2)**

or

$$\frac{-d[reactant]}{dt}\ /\ \frac{d[reactant]}{dt}\ /\ \frac{d[product]}{dt}$$
(5)

(*b*) DESCRIBE: **cross (print)** under (behind) flask **//**
obscured (no longer visible, no longer legible) //
when viewed through **same (constant) depth (height) of solution** in each run **/**
using **same or identical flask (vessel)** in each run ANY TWO: (6 + 3)

or

light meter reading //
reaches same value //
when viewed through **same (constant) depth (height) of solution** in each run **/**
using **same or identical flask (vessel)** in each run

ANY TWO: (6 + 3)

or

pH meter (probe) reading / conductivity meter (probe) reading //
**reaches same value** (6 + 3)

(*c*) COPY X: **24.0 (24)** g/L (3)
18. 0 (18), 12.0 (12), 6.0 (6) g/L (3)

Column X	Marks
Concentration $Na_2S_2O_3$ (g /L)	
30.0	
30 × 0.8 = **24.0 (24)**	(3)
30 × 0.6 = **18. 0 (18)**	
30 × 0.4 = **12.0 (12)**	(3)
30 × 0.2 = **6.0 (6)**	
0	

(*d*) (*i*) COPY Y: **0.02**0 s^{-1} (3)
0.016, 0.012, 0.008, 0.004 s^{-1} (3)

Column Y	Marks	Notes
r (s^{-1})		
0.020	(3)	
0.016		*1 mark to be deducted*
0.012	(3)	*for any one of these four values incorrectly rounded*
0.008		*but make at most*
0.004		*one deduction.*
0		

(*ii*)   PLOT: **both axes correctly labelled concentration (g/L) and rate (*r*, s⁻¹)**   (3)
appropriate scales on both axes   (3)
five points plotted correctly   (3)
straight line through origin / 6th point plotted correctly and line (curve) through them   (3)
[Not plotted on graph paper (–3).]
[Where concentration versus time plotted, maximum (6) marks.]
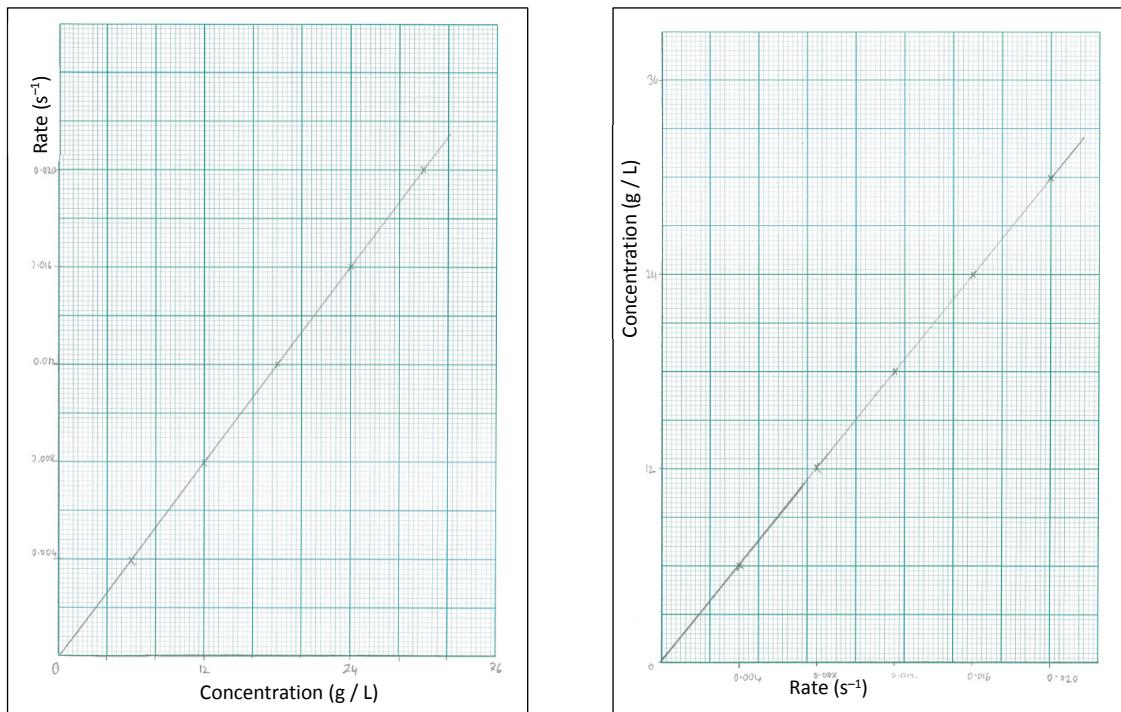
(*iii*)   WHAT: **concentration** of sodium thiosulfate is directly **proportional to (varies directly with) rate (*r*, 1/*t*)**   (3)
[Allow '*direct relationship between concentration and rate (r, 1/t)*', and '*straight line through origin*' and '*linear relationship between concentration and rate (r, 1/t)*' and '*rate increases as concentration increases*'.]
['*Inversely*' cancels '*proportional*', '*varies indirectly*' cancels '*varies directly*'.]

(*e*)   DESCRIBE: **repeat using water baths / repeat heating solutions using hotplate (Bunsen burner) //**
at a number of (several) **different (stated) temperatures //**
with same (fixed) volume(s) and **concentration(s)** of sodium thiosulfate and HCl **/**
repeat a specified run from examination question, e.g. repeat Run 3 //
record reaction times (rates) / analyse data collected **/**
plot graph of temperature versus reaction rates (inverse times)

ANY THREE: (3×3)

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*) WHY: chemical **properties matched (fitted) better** in that order **/**
to ensure periodic recurrence of chemical **properties /**
elements with similar chemical **properties** were **listed in columns (groups) /**
listing these **by atomic mass (weight) did not group them with elements of similar** chemical **properties**   (6)
[Allow '*Mendeleev thought tellurium's atomic mass had been incorrectly measured*'.]

(*b*) IDENTIFY: **3** and **//**
2   **(4 + 2)**
[Order not important.][Allow orbitals if given, e.g. 3*s* and 2*s*.]

(*c*) IDENTIFY: X = **Ba //**
Z = **56**   (2 × 3)

(*d*) WRITE: (*i*)   **2 / +2 //**
(*ii*)   **4 /+4**   (2 × 3)

(*e*) STATE: **equal (same) volumes of gases contain equal (same) numbers of molecules (particles, moles) //**
at the same (constant) temperature and pressure   (2 × 3)
['*Amounts*' unacceptable instead of '*volumes*'; '*all temperatures and pressures*' and '*at s.t.p.*' unacceptable instead of '*at the same (constant) temperature and pressure*'.]

(*f*) CALCULATE: **4.5** g per 500 cm^3 (6)

0.9 (w/v) $\Rightarrow$ **0.9 g per 100 cm^3 / 9 g per litre**	(3)
4.5 g per 500 cm^3	(3)

(*g*) IDENTIFY: (*i*)   *intramolecular:* **polar (covalent)** bonds within ammonia molecule(s) **//**
(*ii*)   *intermolecular:* **hydrogen** bonds **(dipole-dipole, van der Waals** forces**)** between ammonia molecules   **(4 + 2)**
[Take order of question unless statements clearly identified as intermolecular or intramolecular]

(*h*) (*i*) WRITE: **C$_{10}$H$_{12}$O$_2$**
[Allow **condensed formula with 10C, 12H, 2O**.]

(*ii*) NAME: **IR (ir, infrared)** spectrometry or spectroscopy **/ uv**-visible **(UV**-vis**)** spectrometry or spectroscopy **/ MS {mass spectrometry (spectroscopy)} / nmr (nuclear magnetic resonance** spectroscopy**) / x-ray crystallography (diffraction), etc**
    (4 + 2)

(*i*) WRITE: **Cu + 2AgNO$_3$ $\rightarrow$ Cu(NO$_3$)$_2$ + 2Ag**
    FORMULAE: (3) BALANCING: (3)

(*j*)   HOW: **calcium hydrogen carbonate decomposes (breaks down, reacts) /**
calcium hydrogencarbonate converted **to calcium carbonate ($CaCO_3$, limescale,**
limestone) /
a precipitate (an **insoluble** product**)** is formed   (6)
[Information can be conveyed in a chemical equation.]

(*k*)   **A** EXPLAIN: $SO_2 + \frac{1}{2} O_2 \rightarrow SO_3$ **//**
$SO_3 + H_2O \rightarrow H_2SO_4$ (2 × 3)

or
$SO_2 + H_2O \rightarrow H_2SO_3$ **//**
$H_2SO_3 + \frac{1}{2} O_2 \rightarrow H_2SO_4$ (2 × 3)

or
$SO_2 + \frac{1}{2} O_2 + H_2O \rightarrow H_2SO_4$ (6)

   B HOW: aluminium object to be anodised (it) is **made anode (positive electrode, +) //**
in dilute **sulfuric acid** electrolyte **/ in acidified water** electrolyte   (2 × 3)

QUESTION 5

(*a*) DEFINE: **space (volume, region)** around the nucleus of an atom **//**
where there is a relatively **high probability (possibility) of finding an electron / where an electron is likely to be found**
['*Area*' around nucleus not acceptable.]

or

approximate **solution //**
to a Schrödinger wave **equation** (2 × 3)

WRITE: $1s^2\,2s^2\,2p^2\,/1s^2\,2s^2\,2p_x^{\,1}2p_y^{\,1}$ (3)
[Allow subscripts instead of superscripts.]
[Arrows to represent numbers of electrons acceptable but sublevel symbols must be given.]

HOW MANY: **4** (3)

(*b*) WHY: **orbitals do not have defined volumes /**
Heisenberg's uncertainty principle /
it is impossible (difficult) to measure accurately both **position and momentum (velocity) of an electron** in an atom simultaneously **/**
wave-particle duality of electron **/ electrons have wave nature / electrons have wave motion / distance between electron** in an atom **and nucleus always changing / probability of finding an electron** in an atom **non-zero except at infinity / probability exists of finding an electron** in an atom **anywhere** (3)
['*Distance between electron and nucleus difficult to measure*' insufficient on its own.]

STATE: **half** the **distance between** the **nuclei (centres) //**
of two atoms of (an, the, the same) element joined by a single **covalent bond / of two identical atoms joined by a** single **covalent bond** (2 × 3)
[Accept information given in a labelled diagram.]

(*c*) (*i*) DESCRIBE: **increases (increasing) //**
ACCOUNT: **additional shell(s) {**main **energy level(s)}** overcome(s) increasing nuclear charge (2 × 3)
[DESCRIBE and ACCOUNT are linked.]

(*ii*) ACCOUNT: effective **nuclear charge increasing / number protons (nuclear charge, atomic number) increasing** with same screening effect by electrons in first shell (3)

(*d*) DEFINE: minimum **energy to remove //**
most loosely bound electron completely (to infinity) (2 × 3)

WHY: **increasing** effective **nuclear charge / increasing number protons (atomic number)** with same screening effect by electrons in first shell **//**
smaller atomic radius / atomic size decreasing (2 × 3)

(*e*) HOW: (*i*) **six values ⇒ six electrons / each value ⇒ one electron** **(4)**

(*ii*) **gradual (steady) increase for first four values ⇒ four electrons in** the outer (second) main energy **level (shell) / first four values** numerically **close (**all **low,** all **lower) ⇒ four electrons in** the outer (second) main energy **level (shell) /**
last two values very **high (higher) ⇒ two electrons in** the inner (first) main energy **level (shell) /**
large **jump (large increase) after 4ᵗʰ value (after 6223, before 5ᵗʰ value, before 37831) ⇒**
two (four) electrons of the six in one **level (shell)** and four (two) in the other **(4)**

QUESTION 6

(*a*)   IDENTIFY: **methane (CH$_4$)**

   GIVE: **fuel /production of hydrogen / steam reforming / production of ammonia / production of fertilizer**

   WHY: **global warming** / enhanced **greenhouse gas (effect) / traps heat** that should escape to atmosphere / **climate change / rising sea levels / melting polar ice-caps / destruction of some** wildlife **habitats / threat to survival of** some wildlife **species / affects crop yields, etc]**
   ['*Damages ozone*' cancels correct response.]

(**5** + 3 + 3)

(*b*)   EXPLAIN: **stronger (more) intermolecular {van der Waals, London (dispersion)} bonds (forces, interactions) / more electrons** present to create intermolecular forces   (6)

(*c*) (*i*) WRITE: **C$_7$H$_{16}$ → C$_6$H$_5$CH$_3$ + 4H$_2$ / C$_7$H$_{16}$ → C$_7$H$_8$ + 4H$_2$ / C$_7$H$_{16}$ → + 4H$_2$**

FORMULAE: (3) BALANCING: (3)

   (*ii*) WHAT: **increase (improve) octane rating (number, value)** of a fuel **/ reduces tendency** of fuel **to cause knocking / make more fuel (compounds, hydrocarbons, molecules) of higher demand / increase value of products / make more efficient fuel /makes molecules (compounds, hydrocarbons) that are cyclic**

(3)

(*d*) (*i*) DRAW:

but-2-ene				2-methylbutane	
			CH$_3$CH=CHCH$_3$		
				(CH$_3$)$_2$CHCH$_2$CH$_3$	

(2 × 3)

   [In expanded structures the Hs need not be explicitly written.]

   (*ii*) DEDUCE: **C$_3$H$_6$**   (3)
         [Accept structure]

(*e*)   STATE: **heat** change **for a reaction //**
depends only on initial and final states / is same whether reaction **takes place in one or more stages / is independent of path taken / is sum** of heat changes **for all stages**

(2×3)

CALCULATE: **183.2** kJ   (9)

$$
\begin{aligned}
\Delta H_{cracking} &= \Sigma \Delta H_{formation\ products} \quad - \quad \Sigma \Delta H_{formation\ reactants} \\
&= [(-9.3) + (-178.4) + (20.0)]\ \text{kJ}\ (3) - (-350.9)\ \text{kJ}\ (3) \\
or \quad &= [(-9.3) + (-178.4) + (20.0)]\ \text{kJ}\ (3) + 350.9\ \text{kJ}\ (3) \\
or \quad &= -167.7\ \text{kJ}\ (3) + 350.9\ \text{kJ}\ (3) \\
and \quad &= 183.2\ \text{kJ}\ \quad (3)
\end{aligned}
$$

or

$C_{12}H_{26}$	$\rightarrow$ 12C + 13H_2	ΔH = 350.9 kJ	(3)
4C + 4H_2	$\rightarrow$ C_4H_8	ΔH = −9.3 kJ	
5C + 6H_2	$\rightarrow$ C_5H_{12}	ΔH = −178.4 kJ	(3)
3C + 3H_2	$\rightarrow$ C_3H_6	ΔH = 20.0 kJ	
$C_{12}H_{26}$	$\rightarrow$ C_4H_8 + C_5H_{12} + C_3H_6	ΔH = 183.2 kJ	(3)

or

$C_{12}H_{26}$	$\rightarrow$ 12C + 13H_2	ΔH = 350.9 kJ	(3)
12C + 13H_2	$\rightarrow$ C_4H_8 + C_5H_{12} + C_3H_6	ΔH = −167.7 kJ	(3)
$C_{12}H_{26}$	$\rightarrow$ C_4H_8 + C_5H_{12} + C_3H_6	ΔH = 183.2 kJ	(3)
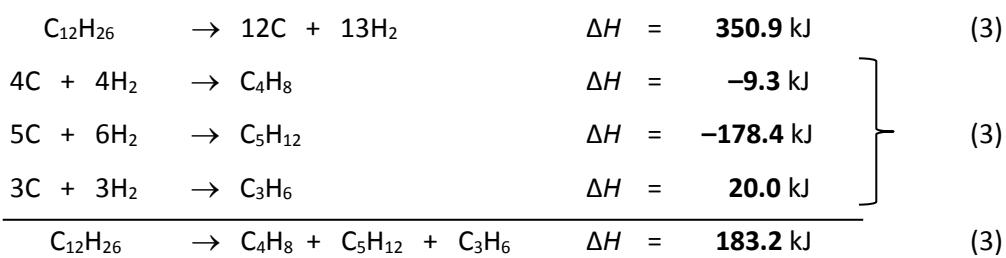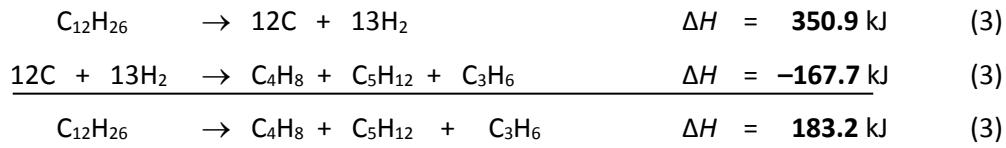
[Final Answer   **C_4H_8 + C_5H_{12} + C_3H_6 $\rightarrow$ $C_{12}H_{26}$ ΔH = −183.2 kJ** is worth (6) marks.]

[Equations not essential, however final answer **−183.2** kJ is worth only (3) marks if not accompanied by an equation or if accompanied by an equation other than that for cracking in reverse.]

QUESTION 7

(*a*) WHAT: state in which **rate of forward reaction** is **equal to rate of reverse reaction** /
state reached at which **concentrations of reactants and products** are **constant** **(5)**
[Allow $r_f = r_r$ or $r_f = r_b$.]

WHY: both **reaction(s) continue(s) / reaction doesn't stop** (3)

STATE: systems **in (at) equilibrium //**
react to **oppose (minimise, relieve)** applied **stress(es) {disturbance(s)}** (2 × 3)
[Instead of '*stress(es){disturbance(s)}*' accept '*change in temperature, pressure or number of moles (concentrations)*' if all three {temperature, pressure and moles (concentrations)} are given.]

(*b*) WRITE: $K_c = \dfrac{[NO_2]^2}{[N_2O_4]}$ (6)
[Do not accept inverted expression.]

(*c*) CALCULATE: **0.05** mol per litre **N_2O_4** and **0.1** mol per litre **NO_2** (18)

Candidate takes 2*x* moles/l **NO_2** at equilibrium	Candidate takes *y* moles/l **NO_2** at equilibrium

Candidate takes 2*x* moles/l **NO_2** at equilibrium

$$N_2O_{4\,(g)} \quad \leftrightarrows \quad 2NO_{2\,(g)}$$

Start: 1 mol   0 mol
      0.1 mol/l   0 mol/l   (3)

Equil: **0.1 − *x*** mol/l   **2*x*** mol/l   (3)

$\dfrac{4x^2}{0.1-x}$ = 0.2 / $\dfrac{(2x)^2}{0.1-x}$ = 0.2 /

$4x^2 + 0.2x − 0.02 = 0$ / $2x^2 + 0.1x − 0.01 = 0$ /

$x^2 + 0.05x − 0.005 = 0$ (3)

$x = \dfrac{-(0.2)\pm\sqrt{(0.2)^2-4(4)(-0.02)}}{2\times 4}$ /

$x = \dfrac{-(0.1)\pm\sqrt{(0.1)^2-2(-0.01)}}{2\times 2}$ /

$x = \dfrac{-(0.05)\pm\sqrt{(0.05)^2-4(-0.005)}}{2}$

or $(2x + 0.2)(2x − 0.1) = 0$ / $(x + 0.1)(2x − 0.1) = 0$ / $(x + 0.1)(x − 0.05) = 0$

x   =   **0.05** mol/l   (3)

[N_2O_4]   =   0.1 − *x*   = **0.05** mol/l   (3)
[NO_2]   =   2*x*   = **0.1** mol/l   (3)

Candidate takes *y* moles/l **NO_2** at equilibrium

$$N_2O_{4\,(g)} \quad \leftrightarrows \quad 2NO_{2\,(g)}$$

Start: 1 mol   0 mol
      0.1 mol/l   0 mol/l   (3)

Equil: **0.1 − ½*y*** mol/l   **y** mol/l   (3)

$\dfrac{y^2}{0.1-½y}$ = 0.2 /

$y^2 + 0.1y − 0.02 = 0$ (3)

$y = \dfrac{-(0.1)\pm\sqrt{(0.1)^2-4(-0.02)}}{2}$

or $(y + 0.2)(y − 0.1) = 0$

y   =   **0.1** mol/l   (3)

[N_2O_4]   =   0.1 − ½*y*   = **0.05** mol/l   (3)
[NO_2]   =   *y*   = **0.1** mol/l   (3)

Candidate working with **2x** moles **NO₂** at equilibrium

$$N_2O_{4\,(g)} \quad \leftrightharpoons \quad 2NO_{2\,(g)}$$

Start: 1 mol   0 mol

Equil: **1 − x** mol   **2x** mol   (3)
Equil: **(1 − x) ÷ 10** mol/l   **2x ÷ 10** mol/l   (3)

$$\frac{4x^2 \div 100}{(1-x)\div 10} = 0.2 \quad / \quad \frac{\left(\frac{2x}{10}\right)^2}{\left(\frac{1-x}{10}\right)} = 0.2 \quad / \quad \frac{4x^2}{(1-x)} = 2 \quad /$$

4x² + 2x − 2 = 0 /

2x² + x − 1 = 0 / x² + 0.5x − 0.5 = 0   (3)

$$x = \frac{-(2)\pm\sqrt{(2)^2 - 4(4)(-2)}}{2\times 4} \quad /$$

$$x = \frac{-(1)\pm\sqrt{(1)^2 - 4(2)(-1)}}{2\times 2} \quad /$$

$$x = \frac{-(0.5)\pm\sqrt{(0.5)^2 - 4(-0.5)}}{2}$$

or (2x + 2)(2x − 1) = 0 / (2x − 1)(x + 1) = 0 /
(x + 1)(x − 0.5) =   0

  x   = **0.5** mol   (3)

   [N₂O₄]   = (1 − x) ÷ 10 = **0.05** mol/l   (3)
   [NO₂]   = 2x ÷ 10 = **0.1** mol/l   (3)

Candidate working with y moles **NO₂** at equilibrium

$$N_2O_{4\,(g)} \quad \leftrightharpoons \quad 2NO_{2\,(g)}$$
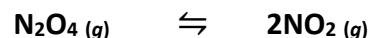
Start: 1 mol   0 mol

Equil: **1 − ½y** mol   **y** mol   (3)
Equil: **(1 − ½y) ÷ 10** mol/l   **y ÷ 10** mol/l   (3)

$$\frac{y^2 \div 100}{(1-\frac{1}{2}y)\div 10} = 0.2 \quad / \quad \frac{y^2}{1 - \frac{1}{2}y} = 2 \quad /$$

y² + y − 2 = 0   (3)

$$y = \frac{-(1)\pm\sqrt{1^2 - 4(-2)}}{2}$$

or (y + 2)(y − 1) = 0

  y   = **1** mol   (3)

   [N₂O₄]   = (1 − ½y) ÷ 10 = **0.05** mol/l   (3)
   [NO₂]   = y ÷ 10 = **0.1** mol/l   (3)

[Chemically impossible solution of correct quadratic equation also used to find concentrations, deduct (1) mark.]
[Do not award last (6) marks for quadratic equation with two chemically impossible solutions.]
[Do not allow mixing and matching of marks within boxes.]
[Where inverted K_c expression used, do not award (3) marks for setting up quadratic.]

(*d*)   EXPLAIN: **low(er) temperature (decrease in temperature) favours (results in, produces more) N₂O₄ {left side, reverse, exothermic (heat producing) reaction} /**

   high(er) temperature would **favour (result in, produce more) NO₂ {right side, forward, endothermic (heat absorbing) reaction}**   (3)

   DEDUCE: decomposition **endothermic**   (3)
   [Linkage here. EXPLAIN marks only available if DEDUCE marks awarded but order of answering parts unimportant]

(*e*)   WOULD: **no** change (effect) **/ none**   (3)

   EXPLAIN: **K_c constant at given temperature** even if concentrations change / **only change in temperature will result in change in K_c**   (3)
   [WOULD and EXPLAIN linked; order of answering parts unimportant; WOULD marks may be awarded if correct response to WOULD is inferred in correct EXPLAIN statement.]

QUESTION 8

(a) WHAT: colourless to **purple (pink)** **to** brown to **colourless (white)** /
colourless to purple (pink) to **brown to colourless (white)** (3)

EXPLAIN: **MnO_4^- {Mn(VII)} changes to / MnO_2 {Mn(IV)} changes to** (3)
Mn^{2+} {Mn(II)} (3)
[Allow Mn^{7+} for Mn(VII) and Mn^{4+} for Mn(IV)]
[Oxidation of **MnO_4^- {Mn(VII), Mn^{7+}}** instead of reduction not acceptable.]
[WHAT and EXPLAIN linked]

MARK (i) (3)
CLEARLY:

 /
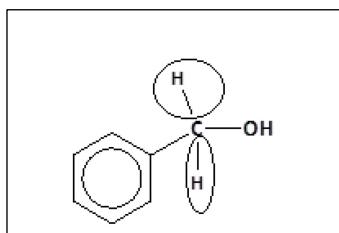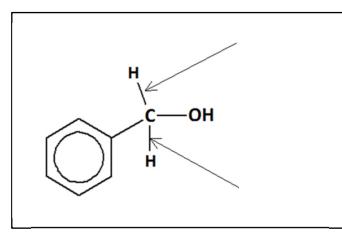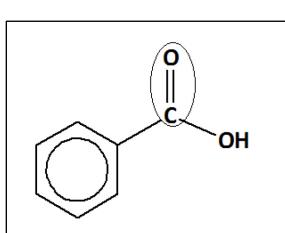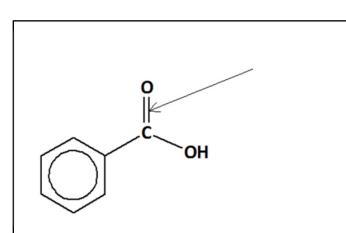
(ii) (3)

 /

(b) GIVE: A = **propanal //**
B = **propanone** (2 × 3)
[Correct order essential unless substances clearly labelled A and B.]

DRAW: (2 × 3)

propanal	propanone
CH_3CH_2CHO	**CH_3COCH_3**
C_2H_5CHO	**$(CH_3)_2CO$**

[Aldehyde H must be explicitly shown, other Hs need not be explicit.]

(c) IDENTIFY: **hydrogen / H_2 //**
nickel (Ni, platinum, Pt, palladium, Pd, copper, Cu, rhodium, Rh, ruthenium, Ru) catalyst
(2 × 3)

[Allow any order of response here.]

(*d*) SUGGEST: **Tollens' reagent / ammoniacal silver nitrate / silver(I) oxide (Ag₂O) / Fehling's reagent /**
Benedict's reagent / copper(II) hydroxide {Cu(OH)₂} (6)

(*e*) NAME: **methyl ethanoate / ethyl methanoate** (6)
[Full or condensed ester formula acceptable here. Molecular formula $C_3H_6O_2$ insufficient.]

IDENTIFY: (3 + 2)

NAME:	methyl ethanoate	ethyl methanoate	
IDENTIFY:	**methanol / CH₃OH** **ethanoic acid / CH₃COOH**	**ethanol / C₂H₅OH** **methanoic acid / HCOOH**	**(3 + 2)**

[NAME and IDENTIFY are linked and IDENTIFY marks only available where NAME marks awarded.]
[Alcohol and carboxylic acid may be identified by name, condensed formula or structure.]

QUESTION 9

(*a*)   DEFINE: (*i*)   **proton (H⁺) acceptor //**

               (*ii*)   two species that **differ by a proton (H⁺)**   (2 × 3)

                         [Examples insufficient on their own.]

     WHAT: **H₃O⁺ / hydronium ion**   (3)

(*b*)   DEFINE: pH = **$-\log_{10}$ [H⁺]** / **$-\log_{10}$ [H₃O⁺]** / **minus log** base 10 **hydrogen ion concentration**

                   expressed in moles per litre   (3)

     ACCOUNT: [Allow *'hydrochloric'* for HCl, *'sulfuric' for* H₂SO₄ and *'methanoic'* for HCOOH.

                   Allow *H⁺, proton, H₃O⁺* or *hydronium ion* for*' hydrogen ion'.*]

(*i*) & (*ii*)   First (9) marks available from **one** of the boxes below.

RELEVANT HCl information

0.10 M **HCl produces 0.1**0 M **H⁺** ion **/ pH HCl = –log (0.1**0**)**   (6)

or

HCl monoprotic (monobasic) / one molecule **HCl produces one H⁺ ion //**

HCl is strong (fully dissociated into H⁺ ions, **a good proton donor)**   (2 × 3)

and

RELEVANT H₂SO₄ information

0.10 M **H₂SO₄ produces 0.2**0 M **H⁺** ion **/**

pH H₂SO₄ = –log (0.20**) /**

H₂SO₄ diprotic (dibasic) /

one molecule **H₂SO₄ produces two H⁺** ions **/**

H₂SO₄ produces (has) more (twice as many) H⁺ ions as HCl   (3)

---

or

RELEVANT H₂SO₄ information

0.10 M **H₂SO₄ produces 0.2**0 M **H⁺** ion **/ pH H₂SO₄ = –log (0.2**0**)**   (6)

or

H₂SO₄ diprotic (dibasic) /

one molecule **H₂SO₄ produces two H⁺** ions **/**

H₂SO₄ produces (has) more (twice as many) H⁺ ions as HCl   (3)

and

RELEVANT HCl information

0.10 M **HCl produces 0.1**0 M **H⁺** ion **/ pH HCl = –log (0.1**0**)**   (3)

---

and

RELEVANT HCOOH information

0.10 M **methanoic acid** (**HCOOH) solution produces 4.27 × 10⁻³ M (less than**

0.10 M**) H⁺** ion **/**

pH HCOOH = inverse log (–2.37) {antilog (–2.37)} /

HCOOH is **weak {slightly (not fully) dissociated** into H⁺ ions, **a poor proton donor} /**

HCOOH weaker than HCl   (3)

USE: (*iii*) $K_a = \mathbf{1.82 \times 10^{-4}}$ (6)

$[H^+] = $ **inverse log (−2.37) */ antilog (−2.37)* / 4.27 × 10⁻³ / 10⁻²·³⁷** (3)
*Omission of minus loses this (3)

$\Rightarrow K_a = \dfrac{[H^+][A^-]}{[HA]} \left(\dfrac{[H^+]^2}{[HA]} , \dfrac{[H^+]^2}{[0.1]} \right) /$

$[H^+] = \sqrt{K_a[HA]} \ / \ 4.27 \times 10^{-3} \ = \sqrt{K_a[0.1]} \ / \ [H^+]^2 = K_a[HA] / (4.27 \times 10^{-3})^2 = K_a(0.1)]$

$K_a = \mathbf{1.82 \times 10^{-4}}$ (3)

[acid] = [HA] = [HX] = $M = M_a$

(*iv*) pH = **2.52** (3)

$pH = -\log\sqrt{K_a[HA]}$***= $-\log\sqrt{1.82 \times 10^{-4}[0.05]}$* = 2.52** (3)
*Omission of minus loses this (3)

[acid] = [HA] = [HX] = $M = M_a$

(*c*) DRAW: **axes labelled (pH and volume) //**
curve of correct shape with steep rise at 25 cm³ **//**
vertical part mostly above pH = 7 //
steep rise coincides with 25 cm³ NaOH

ANY THREE: (3 × 3)

[Allow correct work with volume
scale increasing from right to left
or pH decreasing on
y-axis towards 0.]
[Allow volume on *y*-axis.]
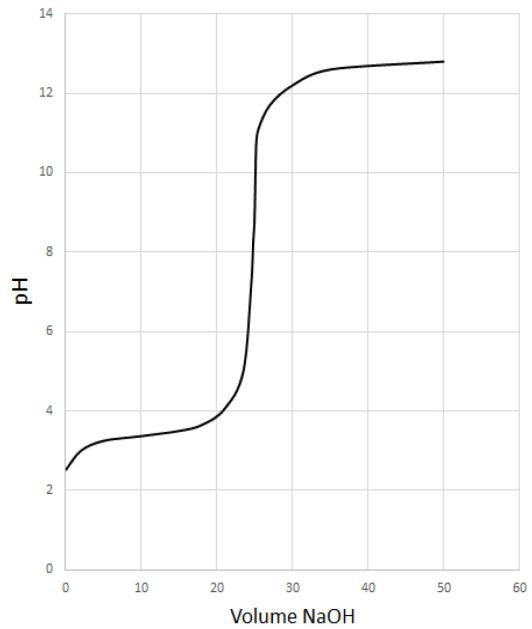
NAME: **phenolphthalein** (6)

EXPLAIN: **colour change (**indicator **range) coincides with sharp rise on graph /**
colour change occurs > 7 /colour change occurs between 7 and 10 /
indicator **range is 8.3 − 10** (2)
[NAME and EXPLAIN linked]

QUESTION 10

(*a*)   DRAW: conical **flask** containing vapour (liquid) **//**
aluminium **foil** lid **with** pin**hole (bung with** small **hole) //**
rubber band (only acceptable with the foil option) **//**
immersed **in beaker** of boiling (hot) **water //**
thermometer (temperature probe, temperature sensor) shown in water **//**
heat source / symbol for heat source
[At least one correct label essential; unlabelled diagram maximum (3 × 2).]
[No diagram = maximum (3 × 2).]

ANY FOUR POINTS: **4** + (3 × 2)

or

vapour in **gas syringe //**
liquid **injected into large syringe** via rubber seal **//**
by needle of **small syringe //**
gas syringe in **oven (water bath, steam jacket) / heat source indicated //**
thermometer (temperature probe, temperature sensor) shown in oven (water bath, steam jacket)
[Syringes should be recognisable; injection shown or mentioned.]
[At least one correct label essential; unlabelled diagram maximum (3 × 2).]
[No diagram = maximum (3 × 2).]

ANY FOUR POINTS: **4** + (3 × 2)
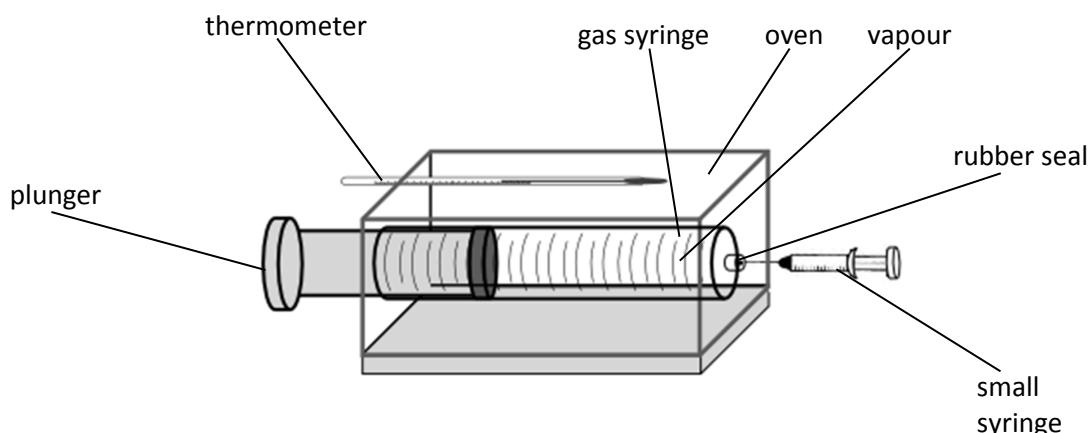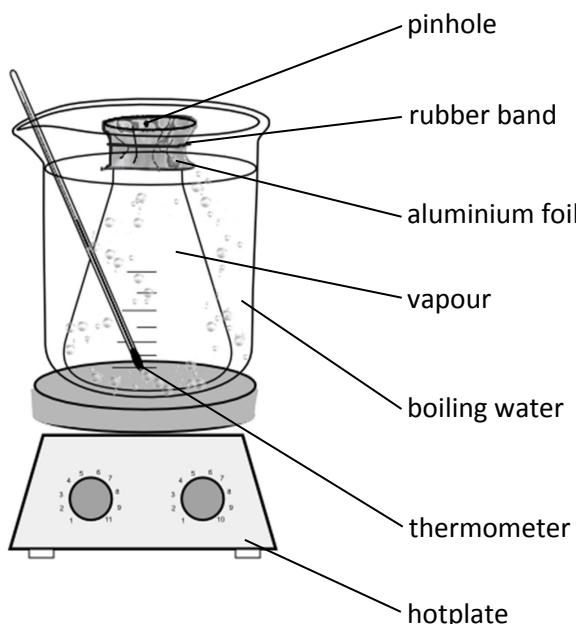
(*i*)   CALCULATE: 8.787×10^{-3} moles [8.7×10^{-3} to 9×10^{-3} moles]   (9)

$n = \dfrac{pV}{RT}$ / $pV = nRT$ /

$n = \dfrac{1.01 \times 10^5 \times 268 \times 10^{-6}}{8.3 \times 371.15}$ / $1.01 \times 10^5 \times 268 \times 10^{-6} = n \times 8.3 \times 371.15$ (6)

$n = 8.787 \times 10^{-3}$ moles [8.7×10^{-3} to 9×10^{-3} moles]   (3)

[Treat an incorrect multiple of any of the possible answers allowed by the range above as a mathematical slip. Treat use of temperature in °C as another slip.]

/

$\dfrac{p_1 V_1}{T_1} = \dfrac{p_2 V_2}{T_2}$ / $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$ /

$\dfrac{101 \times 268}{371.15} = \dfrac{101.325 \times V_2}{273.15}$ / $v_2 = \dfrac{101 \times 268 \times 273.15}{101.325 \times 371.15}$ / $v_2 = \dfrac{268 \times 273.15}{371.15}$ / $V_2 = 196.60$ cm^3 (6)

$n = \dfrac{196.60}{22400} = 8.787 \times 10^{-3}$ moles [8.7×10^{-3} to 9×10^{-3} moles]   (3)

[Treat an incorrect multiple of any of the possible answers allowed by the range above as a mathematical slip. Treat use of temperature in °C as another slip.]

(*ii*)   FIND: **32 or 31**   (6)

$n = \dfrac{m}{M_r}$ / $M_r = \dfrac{m}{n}$ / $M_r = \dfrac{0.28}{8.787 \times 10^{-3}}$ (3)

$31.9 = \mathbf{32}$ **[Accept 32 or 31]**   (3)

Deduct 1 mark if answer not rounded correctly to a whole number.
No penalty if relative molecular mass is given units of mass.

(*b*)   WHAT: **helium (He) nucleus /**
                             particle consisting of **two protons** and **two neutrons /**

                             $^{4}_{2}$**He**   /   **He^{2+}**   (6)

   (*i*)   WHAT: alpha particles were expected to **pass straight through /**
                             alpha particles passing through expected to be **undeflected (**no more than **slightly
                             deflected) /**
                             small angles of deflection (repulsion) for some alpha particles passing through   (6)
                             [Reference to '*large angles*' or '*straight back*' contradicts another correct statement.]

   (*ii*)   HOW: **some (a few)** alpha particles were **deflected (repelled) at large angles //**
                             a few (some) alpha particles **were reflected (deflected back, repelled back** along
                             original path**)**

                                                                                                          (2 × 3)

   (*iii*)   HOW: large **electron cloud** surrounding / **atoms mostly empty space** with   (3)
                             small (dense) //
                             nucleus / positive core (centre)   **(2 × 2)**

                             [Marks in (*i*), (*ii*), and (*iii*) are available for **separate**, **clear, labelled** diagrams.]

(*c*)   (*i*)   WHAT: mono**chloroethane /** 1-**chloroethane / ethyl chloride / C$_2$H$_5$Cl**   **(2)**

               NAME: **ionic addition / electrophilic addition**   **(2)**

               DESCRIBE: polar bond in **hydrogen chloride breaks into ions / hydrogen chloride undergoes
                             heterolytic fission / HCl → H$^+$ + (and) Cl$^-$ //**
                             double bond in ethene **breaks with H$^+$ adding** to **(with H$^+$ forming a bond** with**)** one
                             carbon atom **giving carbononium ion (carbocation, C$^+$, intermediate) / double bond
                             breaks and new C-H bond formed** with H$^+$, **giving carbonium ion (carbocation, C$^+$,
                             intermediate) //**
                             **addition of Cl$^-$ to carbonium ion (carbocation, C$^+$, intermediate) gives
                             product (chloroethane)**   (3 × 3)
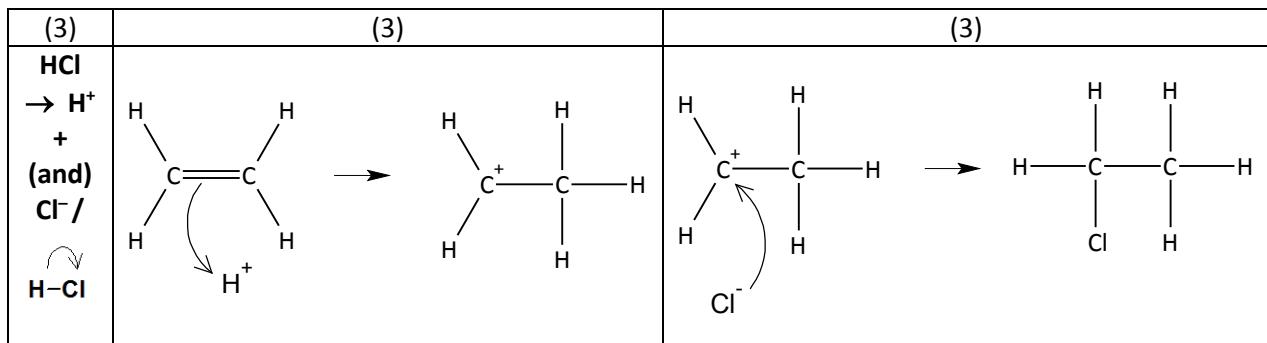
   [Allow cyclic carbocation.]
               [Marks available for diagrams, allow correct use of curly arrows (but not half-arrows
               (fishhooks).]
               [Deduct (3) marks for each of the following errors: H$^+$—Cl$^-$, addition of Cl$^{\delta-}$ instead of
               Cl$^-$ in third step, each reference to radicals, reference to Cl$^-$ adding first and H$^+$ adding
               in third step.]

or

hydrogen of hydrogen chloride approaches double bond end-on **/**
hydrogen chloride (HCl) highly polarised with hydrogen nearest double bond **/**
hydrogen chloride (HCl) becomes (→) $H^{\delta+}$—$Cl^{\delta-}$ with hydrogen nearest double bond **/**
partially charged hydrogen atom ($H^{\delta+}$) from HCl is attracted to double bond //
double bond breaks and new C-H bond formed (**with H^+ adding) giving carbononium**
ion (carbocation, C^+, intermediate) and Cl^- / **double bond breaks and new C-H bond**
formed, giving carbonium ion (carbocation, C^+, intermediate) and Cl^- //
addition of Cl^- to carbonium ion (carbocation, C^+, intermediate) gives
product (chloroethane)   (3 × 3)

(3)	(3)	(3)
H of $H^{\delta+}$—$Cl^{\delta-}$ approaches double bond		
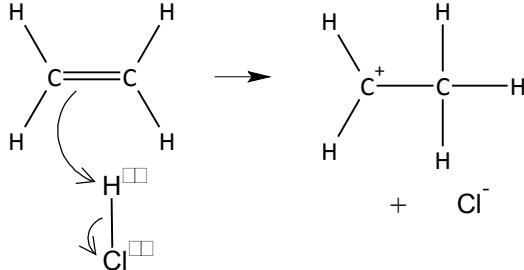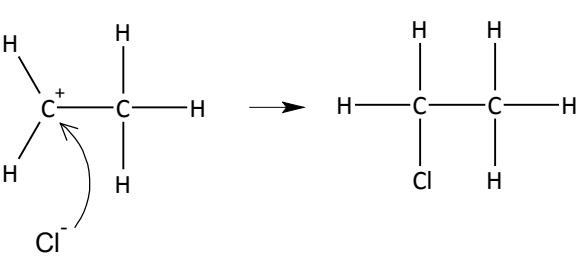
[Allow cyclic carbocation.] [Cl^- not essential in second diagram.]
[Marks available for diagrams, allow correct use of curly arrows (but not half-arrows (fishhooks).]
[Deduct (3) marks for each of the following errors: H^+—$Cl^{\delta-}$, addition of $Cl^{\delta-}$ instead of Cl^- in third step, each reference to radicals, reference to Cl^- adding first and H^+ adding in third step .]

or

polar bond in **hydrogen chloride breaks into ions / HCl → H^+ + (and) Cl^-**   (3)
double bond breaks with H^+ adding to ethene **and simultaneous (followed very**
rapidly by) breaking of bond in nearby **HCl molecule to then allow addition of Cl^-**
giving product (chloroethane) and regenerating a H^+   (6)

(3)	(6)
HCl → H^+ + (and) Cl^-	
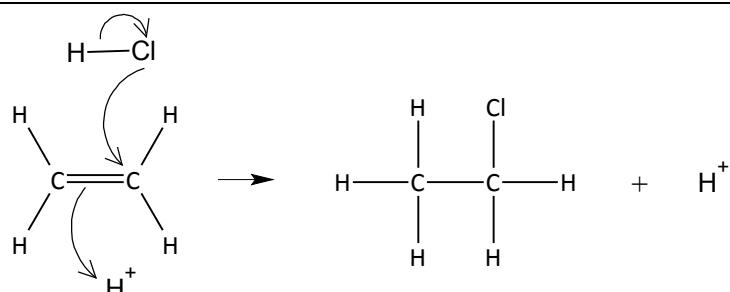
[Marks available for diagrams, allow correct use of curly arrows (but not half-arrows (fishhooks).]
[Deduct (3) marks for each of the following errors: H^+—$Cl^{\delta-}$, addition of $Cl^{\delta-}$ instead of Cl^- in third step, each reference to radicals, reference to Cl^- adding first and H^+ adding thereafter.]

(*ii*)   HOW: **planar** around carbons in ethene to **//**
               tetrahedral around carbons in chloroethane   (2 × 3)

            [Take order of question unless geometries clearly assigned to ethene and chloroethane]

(*iii*)   HOW: **chlorine (Cl$_2$)** / **chlorination //**
               ultraviolet (uv) light   (2 × 3)

            [Allow 3 for '*free radical substitution*' or '*radical chlorination*'.]

QUESTION 11

(*a*)   (*i*)   WHAT: **6.8896 – 6.89** g azurite   (9)

M_r azurite = **344.5***   (3)

$\frac{3.81}{63.5}$ = 0.06 moles Cu $\Rightarrow$ **0.02 (1/50)** moles azurite

                                          (3)

$\frac{m}{344.5}$ = 0.02 moles

m = **6.89** g azurite   (3)

/

M_r azurite = **344.5***   (3)

$\frac{3 \times 63.5}{344.5} \times 100$ = **55.2975 – 55.30%** Cu   (3)

$\frac{3.81}{0.5530}$ = m

m = **6.8896 – 6.89** g azurite   (3)

/

M_r azurite = **344.5***   (3)

3 × 63.5 g Cu in **344.5 g** azurite / **190.5 g Cu** in **344.5 g** azurite   (3)

3.81 g Cu $\Rightarrow \frac{344.5 \times 3.81}{3 \times 63.5}$ / $\frac{344.5 \times 3.81}{190.5}$ = **6.89** g azurite   (3)

[*Addition must be shown for error to be treated as slip.]

  (*ii*)   CALCULATE: **6.63** g malachite   (9)

M_r malachite = **221***   (3)

0.06 moles Cu or 0.02 moles azurite
$\Rightarrow$ **0.03 (3/100)** moles malachite   (3)

0.03 × 221 = **6.63** g malachite   (3)

/

M_r malachite = **221***   (3)

2 × 63.5 g Cu in **221 g** malachite / **127 g Cu** in **221 g** malachite   (3)

3.81 g Cu $\Rightarrow \frac{221 \times 3.81}{2 \times 63.5}$ / $\frac{221 \times 3.81}{127}$ = **6.63** g malachite   (3)

/

M_r malachite = **221***   (3)

2 × 344.5 g / 689 g azurite $\Rightarrow$ **3 × 221 g / 663 g** malachite   (3)

6.89 g azurite $\Rightarrow \frac{663 \times 6.89}{689}$ = **6.63** g malachite   (3)

[**Addition must be shown for error to be treated as slip.]
[Where candidate's work clearly shows one incorrect A_r used to get M_r of azurite and M_r of malachite consistent with this error, award no marks for M_r of azurite and apply slip (–1) for the error in M_r of malachite.]

  (*iii*)   WHAT: **0.224** litres / **224** cm³   (6)

0.01 (1/100) moles CO_2 gas   (3)

0.01 × 22.4 = **0.224** litres / **224** cm³   (3)

/

689 (2 × 344.5) g azurite / **663 (3 × 221) g** malachite $\Rightarrow$ **22.4 l** (**22400** cm³) CO_2 gas   (3)

6.89 g azurite / 6.63 g malachite $\Rightarrow$ **0.224** litres / **224** cm³   (3)

[Use of 24 litres as molar volume not acceptable here.]

  (*iv*)   SUGGEST: **keep it dry / low humidity / use waterproof varnish (coating) / keep it cool / protect from heat / protect from light**   **(1)**

(*b*)   DEFINE: number expressing the **relative attraction of an atom for / measure of tendency for atom to attract //**
shared pair(s) of **electrons / electrons in a covalent bond / bonding pair of electrons**   (2 × 3)

DRAW:

(*i*)	NF$_3$			(3)
(*ii*)	BF$_3$			(3)
(*iii*)	ClF			(3)

[Only bond pairs required for each molecule.]
[BF$_3$ ionic unacceptable but cancellation not applied.]

USE: **trigonal (triangular) planar**   (3)
[Diagram alone insufficient, name essential]

(*iv*)   INDICATE: **partial positive charge on chlorine //**
partial negative charge on fluorine   **(2 × 2)**
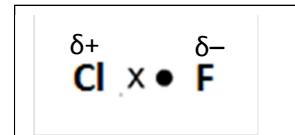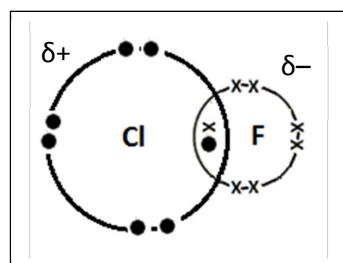
[See original diagram in (*iii*) above or accept new diagram; only bond pair required.]
[Full charges not acceptable.]

(*v*)   PREDICT: **polar** covalent   (3)

(*c*) **A** (*i*) GIVE: **packaging** food **to prevent oxidation (keep food fresh) // packaging to prevent crushing of food (delicate items) // flushing (purging) tanks of flammable liquids (gases, vapours) // freezing (preserving) food (biological specimens, sperm, semen) // remove unwanted skin cells // remove skin cancer (wart**s**, verruca**e**) //** feedstock for **ammonia (fertilizer) industry, //etc**   ANY TWO: **(4 + 3)**

(*ii*) NAME: **carbon dioxide // water vapour // dust // oil particles**   ANY TWO: (2 × 3)
[Allow CO_2 and H_2O.]

(*iii*) EXPLAIN: **cooled //**
compressed (placed under pressure)   (2 × 3)
or
compressed (placed under pressure) //
and **allowed to expand**   (2 × 3)

(*iv*) WHICH: **A**   (3)

(*v*) WHICH: **B**   (3)

B (*i*) DRAW:

(6)

(4)
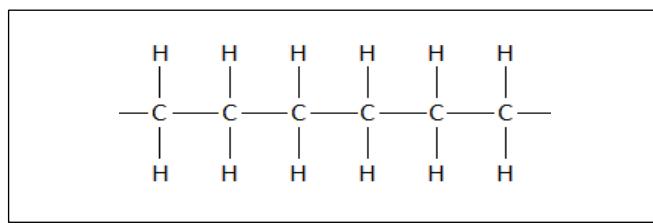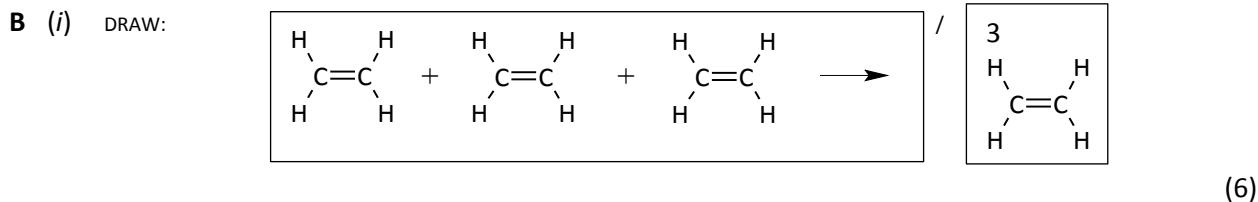
[Three repeating units of poly(ethene), i.e.
six carbons in a chain, two hydrogen atoms attached to each carbon, single bonds.]
[End bonds not required.]
[Where 2 ethenes make a carbon chain with four carbon atoms, award
(3) for ethenes and (2) for chain.]

(*ii*) GIVE: *LDPE:* **more branched / lower melting point / shorter chain length /**
softer (more flexible, not as strong)   ANY TWO: (6 + 3)
[Accept equivalent opposites about HDPE]

(*iii*) WHAT: *HDPE:* organometallic (Ziegler-Natta) **catalyst**   (3)

LDPE: **high(er) pressure(s) /** *LDPE:* **high(er) temperature(s) /**
HDPE: **low(er) temperature(s) /** *HDPE:* **low(er) pressure(s)**   (3)

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