



Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2018

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).



Coimisiún na Scrúduithe Stáit

400@10%

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 ghnóthaíonn 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
301 - 303	29
304 - 306	28
307 - 310	27
311 - 313	26
314 - 316	25
317 - 320	24
321 - 323	23
324 - 326	22
327 - 330	21
331 - 333	20
334 - 336	19
337 - 340	18
341 - 343	17
344 - 346	16
347 - 350	15

Bunmharc	Marc Bónais
351 - 353	14
354 - 356	13
357 - 360	12
361 - 363	11
364 - 366	10
367 - 370	9
371 - 373	8
374 - 376	7
377 - 380	6
381 - 383	5
384 - 386	4
387 - 390	3
391 - 393	2
394 - 396	1
397 - 400	0

QUESTION 1

(a) IDENTIFY: **CaSO₄ (calcium sulfate, SO₄²⁻) / CaCl₂ (calcium chloride, Cl⁻)** (3)
[Cancellation applies.]

(b) DESCRIBE
PROCEDURE: use 25 cm³ **pipette** twice //

previously **rinsed with deionised (distilled, pure) water** / pipette **clean** //

rinsed with the hard water (sample) / pipette **dry** //

read (observe) meniscus (mark) at eye level / meniscus (mark) at eye level /
read bottom of meniscus / bottom meniscus on mark //

do not blow out (dislodge, shake out) last drop from pipette / **allow drainage time //**
wait until pipette fully empty / touch tip against inside (wall of) conical flask
ANY THREE: (6 + 3 + 3)

or

use **burette** to measure out 50 cm³ //

previously **rinsed with deionised (distilled, pure) water** / burette **clean** //

rinsed with the hard water (sample) / burette **dry** //

read (observe) meniscus (mark) at eye level / meniscus (mark) at eye level /
read bottom of meniscus / bottom of meniscus on mark //

keep burette vertical //
remove funnel (ensure part below tap of burette filled) before adjusting to zero
ANY THREE: (6 + 3 + 3)

(c) NAME: (i) **Solochrome Black / Eriochrome Black T** (3)
[Black T insufficient.]

WHAT: (ii) **wine / red** (3)
(iii) **blue** (3)
[Allow (3) for colours reversed.]

(d) (i) IDENTIFY: **pH 10 buffer / buffer with pH > 10 / ammoniacal buffer / buffer 10** (3)

(ii) WHY: **to ensure accurate end point / to keep pH at (about) 10 (at a fixed value) /**
to ensure indicator works properly /
to ensure sharp end point (colour change of indicator) /
to ensure all calcium (magnesium, M²⁺) ions react (complex) with edta /
indicator must be at about pH 10 to work properly (3)

[Allow (6) for (i) 'buffer' and (ii) 'to keep the pH at 10'.]

(e) CALCULATE: (i) 0.000093 (9.3×10^{-5}) moles (3)

$$M = \frac{9.3 \times 0.010}{1000} = 0.000093 \text{ (} 9.3 \times 10^{-5} \text{) moles} \quad (3)$$

(ii) 0.000093 (9.3×10^{-5}) moles (3)

$$M^{2+}: \text{edta} = 1 : 1 \Rightarrow 0.000093 \text{ (} 9.3 \times 10^{-5} \text{) moles} \quad (3)$$

(iii) 0.186 g/l (0.19 g/l) (6)

$$0.000093 \times 20 = 0.00186 \text{ (} 1.86 \times 10^{-3} \text{) moles/l (M)} \quad (3)$$

$$0.00186 \times 100^* = 0.186 \text{ g/l (0.19 g/l)} \quad (3) \quad /$$

$$0.000093 \times 100^* = 0.0093 \text{ (} 9.3 \times 10^{-3} \text{) g/50 cm}^3 \quad (3)$$

$$0.0093 \times 20 = 0.186 \text{ g/l (0.19 g/l)} \quad (3) \quad /$$

$$\frac{50.0 \times M}{1} = \frac{9.3 \times 0.010}{1}$$
$$M = 0.00186 \text{ (} 1.86 \times 10^{-3} \text{) mol/l (M)} \quad (3)$$

$$0.00186 \times 100^* = 0.186 \text{ g/l (0.19 g/l)} \quad (3)$$

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

(iv) 186 p.p.m. (190 p.p.m.) (3)

$$0.186 \times 1000 = 186 \text{ p.p.m. (190 p.p.m.)} \quad (3)$$

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

(f) SUGGEST: **boil water** (3)

scale (scum, precipitate, deposit) as a result of boiling indicates temporary hardness /
repeat **titration (experiment) / titrate again /**
lower titration (experiment) result with filtered, boiled water indicates temporary hardness /
less soap needed to make lather with filtered, boiled water indicates
temporary hardness (2)

[Allow equivalent opposite statements about permanent hardness.]

[The two parts of the answer are linked.]

QUESTION 2

(a) (i) NAME: **condenser** (6)

(ii) WHAT: **to heat (provide energy) to reaction mixture /
to keep solvent (mixture) boiling (hot, heated) /
to keep reaction (mixture) at constant temperature above room temperature /
to help reaction go to(wards) completion (equilibrium) /
to maximise yield / to speed up reaction / to reduce time for reaction /
to help reaction reach (exceed, overcome) activation energy //**
**without loss of solvent (vapour, ethanol, volatile material*) /
without solvent (vapour, ethanol, volatile material*) boiling away (off)** (2 × 3)
[Allow 'evaporation' or 'boil dry' instead of 'boiling away (off)'.] [*Allow 'reactants'.]

(iii) IDENTIFY: **reactants: fat {lard, glyceryl tristearate (tripalmitate), stearin, vegetable (olive, sunflower) oil} //
sodium hydroxide (NaOH, potassium hydroxide, KOH) //**
solvent: ethanol (C₂H₅OH, alcohol) (3 × 2)
[Any order, substances need not be labelled as reactants or solvent.]
[Allow correct structural formulae for reactants and solvent.]
[Cancellation applies except for water.]

(b) (i) WHAT: **oil droplets (small oil drops) in water (in second liquid in which oil is insoluble) /
oil droplets (small oil drops) and water (second liquid in which oil is insoluble) mixed /
oil droplets suspended (dispersed) in water (second liquid in which oil is insoluble) /
fine dispersion of one liquid in a second liquid in which it is insoluble /
two immiscible liquids mixed without a boundary /
colloid of two immiscible liquids** (3)

(ii) NAME: **cyclohexane / dichloromethane (methylene chloride) / diethyl ether (ethoxyethane) /
ethyl ethanoate (ethyl acetate) / petroleum ether, etc** (3)
[Allow any volatile (b.p. < 80 °C), water-immiscible solvent;
methanol, ethanol, propan-2-one (propanone, acetone), etc, not suitable.]

(iii) STATE: **work in fume-cupboard / use breathing mask / avoid flame (igniting solvent, fire) /
release pressure build-up / opening stopper (tap) regularly / invert when opening tap /
keep stopper firmly in place while shaking (mixing) / avoid pointing nozzle at anyone
when releasing pressure (opening tap)** (3)

(iv) HOW: **evaporate solvent / boil off solvent {solvent named at (ii)} / heat to remove solvent /
distil** (3)

(v) WHAT: **3.15 – 3.2 %** (6)

$$\text{density} = \frac{\text{mass}}{\text{volume}} = 1.05 = \frac{\text{mass}}{0.15}$$
$$m = 1.05 \times 0.15 = 0.1575 \text{ g [0.1575 – 0.16 g]} \quad (3)$$
$$\frac{0.1575}{5.0} \times 100 \Rightarrow 3.15\% [3.15 – 3.2\%] \quad (3)$$

[1 mark to be deducted for incorrect rounding off resulting in candidate's answers lying outside given ranges but deduction to be made once only in (v).]

- (c) (i) WHY: **no insoluble impurities (solids, particles) /
hot filtration removes insoluble impurities (solids, particles) /
only impurity (solid, particle) soluble /
sodium chloride (NaCl) soluble //**
- (ii) STATE: **faster / helps dry the crystals**
 ANY CORRECT RESPONSE FOR (i) and ANY CORRECT RESPONSE FOR (ii): (6 + 3)
- (iii) EXPLAIN: measure (compare) **melting points** of both samples (3)
- purer (recrystallized) melting point **higher (closer to correct value) /
 impure (original) melting point lower /
 purer (recrystallized) melting point sharper /
 impure (original) melting point broader (less sharp)** (2)
 [Both parts linked.]
- or*
- CHO gravimetric microanalysis / named spectroscopic technique** (3)
- purer (recrystallized) CHO analysis **closer to correct result /
 impure (original) CHO analysis farther from correct result /
 spectrum of purer (recrystallized) sample shows fewer (no) impurities /
 spectrum of impure (original) sample shows more impurities** (2)
 [Both parts linked.]

QUESTION 3

(a) IS: **exothermic** (3)

JUSTIFY: **temperature goes up / heat given out** (2)
 [JUSTIFY marks only available if marks for 'exothermic' awarded.]

(b) (i) WHY: **distribute heat evenly / avoid taking temperature of a hot (cold) spot (place) / get a more accurate result / ensure complete (fast) reaction** (3)
 [Allow (3) for 'uniform (homogeneous) solution'.]

(ii) SUGGEST: **heat loss to the surroundings / cardboard is not a good insulator / the solution is hotter than the room (surroundings)** (3)

(iii) WHAT: **6 K** (3)

(c) (i) WHY: **bigger temperature rise recorded / giving more accurate result / as a result ΔH more accurate / less percentage error / temperature rise easier to measure accurately** (6)
 [Allow (3) for 'because reaction faster'.] [Reference to heat instead of temperature not acceptable.]

(ii) DRAW
or
DESCRIBE:



liquid pouring from test-tube(s) // onto hand (object, metal) (2 × 3)
 [No marks for any other pictogram but cancellation does not apply.]

(d) CALCULATE: (i) **0.15 moles** (3)

$$M = \frac{150 \times 1.0}{1000} = 0.15 \text{ moles} \quad (3)$$

(ii) **8.3328 kJ [8.3 to 8.333 kJ] / = 8332.8 joules [8300 to 8333 J]** (9)

$m = 0.31 \text{ kg}$ (3) $H = mc\Delta T (mc\Delta\theta) / H = 0.31 \times 4.2 \times 6.4$ (3) $= 8.3328 \text{ kJ [8.3 to 8.333 kJ]}$ (3)	/	$c = 0.0042 \text{ kJ g}^{-1} \text{ K}^{-1}$ (3) $H = mc\Delta T (mc\Delta\theta) / H = 310 \times 0.0042 \times 6.4$ (3) $= 8.3328 \text{ kJ [8.3 to 8.333 kJ]}$ (3)	/
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$c = 4.2 \text{ J g}^{-1} \text{ K}^{-1}$ and $m = 310 \text{ g}$ (3) $H = mc\Delta T (mc\Delta\theta) / H = 310 \times 4.2 \times 6.4$ (3) $= 8,332.8 \text{ joules (J) [8,300 to 8,333 J]}$ (3) Units essential in answer for full marks here.

[Allow (6) for 8,300 to 8,333 without work and not labelled joules (J).]

(iii) **[-55.6 to -55.55 kJ mol⁻¹] or [-55,600 to -55,550 J mol⁻¹]** (6)

$8.3328 \div 0.15 = 55.55 \text{ to } 55.6 \text{ kJ mol}^{-1}$ (3) $\Delta H = -55.6 \text{ kJ mol}^{-1} [-55.6 \text{ to } -55.55 \text{ kJ mol}^{-1}]$ (3)	/	$8,332.8 \div 0.15 = 55,550 \text{ to } 55,600 \text{ J mol}^{-1}$ (3) $\Delta H = -55.6 \text{ kJ mol}^{-1} [-55,600 \text{ to } -55,550 \text{ J mol}^{-1}]$ (3)
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[1 mark to be deducted for incorrect rounding off resulting in candidate's final answer lying outside given range but deduction to be made once only in (d).]

[Ignore negative signs used in work in (ii) but final answer in (iii) must be negative.]

(e) STATE:

(3)

EXPLAIN:

(3)

STATE (3)	EXPLAIN (3)
use more insulation / wrap in cotton wool	gives more accurate temperature rise (change) / stops (reduces) heat loss to surroundings / more accurate result for heat produced in cup
use polystyrene (plastic) cup	gives more accurate temperature rise (change) / stops (reduces) heat loss to surroundings / more accurate result for heat produced in cup / better insulation than cardboard
acid and base 3 K below room temperature initially	heat gain from surroundings and heat lost to surroundings cancel / gives more accurate temperature rise (change) / more accurate result for heat produced in cup
use greater volumes of acid and base	smaller error in total mass / gives more accurate temperature rise (change) / greater temperature rise (change) / more accurate result for heat produced in cup
use acid and base with greater concentrations	greater temperature rise (change) / more accurate result for temperature (heat produced) in cup
use specific heat capacity of solution in calculations	more accurate result for heat produced in cup
allow for specific heat capacity of material of container	more accurate result for heat produced in cup
repeat several times and average	result statistically more accurate / more accurate result for heat produced in cup / gives more accurate temperature rise (change)
measure volumes with pipette (burette)* assuming the readings given are read correct to 1 cm³	reduce error in volumes to 0.1 cm³
use thermometer** with low heat capacity / allow for specific heat capacity of material of thermometer	gives more accurate temperature rise (change) / gives more accurate highest temperature / more accurate result for heat produced in cup
use more sensitive (accurate) thermometer	more accurate result for temperature (heat produced) in cup / more accurate result for heat produced in cup
graph temperature fall after mixing versus time and extrapolate to get temperature at time of mixing	gives more accurate temperature rise (highest temperature) / more accurate result for heat produced in cup

[SUGGEST and EXPLAIN are linked.]

[*Do not allow '**add using pipette (burette)**'.]

[**Do not allow '*use digital thermometer*' as a precaution.]

[Do not allow '*use same quantity (number of moles, volume) of acid and base*'.]

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) WHAT: **measure (determine, find) magnitude of charge on electron /
measure (determine, find) magnitude of charge on e /
measure (determine, find) magnitude of elementary (fundamental) electrical charge (6)**
[Do not allow 'measure (determine, find) mass of electron or e/m '.]
[Do not allow 'calculate' for 'measure (determine, find)'.]

(b) STATE: **decrease //**
GIVE: **effective nuclear charge increasing / number protons increasing / atomic number
increasing** (2 × 3)
[Not linked.]

(c) WRITE: **$1s^2 2s^2 2p^6 3s^2 3p^6 / 1s^2 2s^2 2p_x^2 2p_y^2 2p_z^2 3s^2 3p_x^2 3p_y^2 3p_z^2 / [Ar] //$
 $4s^2 3d^6 / 3d^6 4s^2$** (2 × 3)

[Allow subscripts instead of superscripts.][Allow Ar instead of [Ar].]
[Arrows to represent numbers of electrons acceptable but sublevel symbols must be given.]

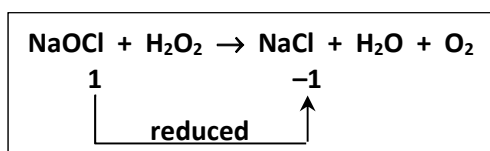
(d) GIVE: **molecules (particles) not point masses / molecules (particles) not points /
molecules (particles) have non-negligible volume / molecules (particles) occupy space //
molecules (particles) attract (repel) one another / intermolecular (van der Waals) forces
(bonds, interactions) / forces between molecules (particles) other than during collisions**
(2 × 3)
[Do not allow 'molecules closer together'.][Allow 'atoms' for 'molecules'.]

(e) IDENTIFY: **$HNO_3 //$
 NO_3^-** (2 × 3)
[Take order of question unless responses clearly identified as acid or conjugate base.]
[Allow (3) for HPO_4^{2-} and PO_4^{3-} .]

(f) USE: NaOCl: **chlorine oxidation state +1 changes (to) oxidation state -1** (3)
 \Rightarrow Cl reduced (3)
[Second (3) only available if first (3) awarded.]

or

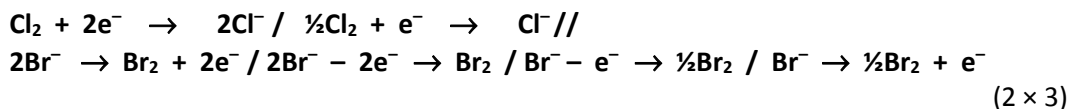
(3) marks for oxidation numbers of chlorine and (3) for species reduced available from:



[Second (3) only available if first (3) awarded.]

- (g) WRITE: $\text{Cl}_2 + 2\text{NaBr} \rightarrow \text{Br}_2 + 2\text{NaCl} / \text{Cl}_2 + 2\text{Br}^- \rightarrow \text{Br}_2 + 2\text{Cl}^- /$
 $\frac{1}{2}\text{Cl}_2 + \text{NaBr} \rightarrow \frac{1}{2}\text{Br}_2 + \text{NaCl} / \frac{1}{2}\text{Cl}_2 + \text{Br}^- \rightarrow \frac{1}{2}\text{Br}_2 + \text{Cl}^-$ FORMULAE: (3) BALANCING: (3)

or



[Charges essential including on electron(s).]

- (h) STATE: **reaction rate increases / reaction speeds up / product formed faster //**
 EXPLAIN: **tetraethyllead acts as a catalyst (radical promoter) / initiates the reaction /**
tetraethyllead provides (breaks up into) ethyl free radicals (C₂H₅•) (2 × 3)

[Not linked.]

[Accept for STATE 'a little chloroethane formed' or 'a little butane formed'.]

- (i) FIND: **C₂H₄O** (6)

$\frac{54.5}{12} / = 4.54$	$\frac{9.1}{1} / = 9.1$	$\frac{36.4}{16} / = 2.275$	(3)
$\frac{4.54}{2.275} = 2$	$\frac{9.1}{2.275} = 4$	$\frac{2.275}{2.275} = 1$	⇒
C₂H₄O			(3)

- (j) EXPLAIN: **quantity (amount, number of p.p.m.) dissolved oxygen (O₂) consumed //**
by biological (biochemical) action in a water supply over 5 days in the dark at 20 °C (2 × 3)

[Allow 19 – 21 °C.]

- (k) A WHICH: **water vapour //**
 GIVE: **it is most plentiful / highest concentration** (2 × 3)
 [WHICH and GIVE linked.]

or

- B GIVE: (i) **iodine (I₂) / carbon dioxide (dry ice, CO₂) / ice (solid H₂O) / glucose (C₆H₁₂O₆) /**
sucrose (C₁₂H₂₂O₁₁) / buckminsterfullerene (buckyballs, C₆₀) / etc //
 (ii) **diamond / graphite / graphene / silicon / silica / quartz / etc** (2 × 3)

QUESTION 5

- (a) DEFINE: (i) **sum (combined number) of protons and neutrons** in the nucleus of an atom / **number of nucleons** in the nucleus of an atom (3)
[Allow 'amount' for 'sum' or 'number'.]

- (ii) **average mass of an atom** of the element / **average mass of isotopes** of the element **taking abundances into account (as they occur naturally)** / **average of mass numbers of isotopes** of the element **taking abundances into account (as they occur naturally)** // **compared to (based on) $1/12^{\text{th}}$ carbon-12 isotope** (3 + 2)

- (b) WHAT: **ionisation** // **acceleration** // **separation / deflection in a magnetic field** (3 × 3)
[Order of responses not important.]
[Award no marks for 'vaporisation' and 'detection' but do not cancel if either or both are listed; cancellation applies to any other 4th process given in addition to the correct three responses.]

- (c) CALCULATE: **24.32** (6)

$$(79 \times 24) + (10 \times 25) + (11 \times 26) = \mathbf{2432} \quad (3)$$

$$2432 \div 100 = \mathbf{24.32} \quad (3)$$

[24.31 without work is worth no marks; 24.31 where work is shown should be marked consequentially]

- (d) (i) DEFINE: **spontaneous decay (disintegration, break-up, splitting) of an atomic nucleus (of atomic nuclei)** // **with emission of different (one or more) types of radiation / with emission of alpha (α) particles, beta (β) particles and (or) gamma (γ) rays** (2 × 3)
[Do not accept 'with emission of two types of radiation'.]

- (ii) WHAT: a **neutron changes into a proton /** and an **electron that is emitted** from nucleus (6)

or



['Atomic number (number of protons) increases by one' is allowable for (6).]

['Beta-particle emitted' is not acceptable.]

[Accept for (6) 'a positron is emitted when a proton changes into neutron'.]

- (iii) WRITE: ${}^{14}_6\text{C} \rightarrow {}^{14}_7\text{N} + {}^0_{-1}e / {}^{14}_6\text{C} \rightarrow {}^{14}_7\text{N} + e^- / {}^{14}_6\text{C} \rightarrow {}^{14}_7\text{N} + {}^0_{-1}e / {}^{14}_6\text{C} \rightarrow {}^{14}_7\text{N} + e^-$ (6)
[Accept '+ β^- ' for '+ e^- '.]

(iv) EXPLAIN: **5730 is the half-life / number carbon-14 atoms halved in 5730 years / twice the current number of carbon-14 atoms 5730 years ago / double the number of carbon-14 atoms when it was alive / half the carbon-14 atoms have decayed** (3)

WHAT MASS: 7.0×10^{-11} g of carbon-14 originally (6)

$$3.0 \times 10^{12} \div 6.0 \times 10^{23} = 5.0 \times 10^{-12} \text{ moles of carbon-14 originally} \quad (3)$$

$$5.0 \times 10^{-12} \times 14^* = 7.0 \times 10^{-11} \text{ g originally} \quad (3)$$

or

$$\text{mass of carbon-14 in a.m.u. originally} = 3.0 \times 10^{12} \times 14^* = 4.2 \times 10^{13} \quad (3)$$

$$4.2 \times 10^{13} \div 6.0 \times 10^{23} = 7.0 \times 10^{-11} \text{ g originally} \quad (3)$$

or

$$\text{mass of one carbon-14 isotope} = 14^* \times 1.66 \times 10^{-27} = 2.324 \times 10^{-26} \text{ kg} \quad (3)$$

$$3.0 \times 10^{12} \times 2.324 \times 10^{-26} = 7.0 \times 10^{-14} \text{ kg originally} / 7.0 \times 10^{-11} \text{ g originally} \quad (3)$$

[*Using 12 instead of 14 here is more than a slip.]

[Allow more exact mass of carbon-14 taken from *Formulae and Tables* booklet, page 83.]

QUESTION 6

(a) EXPLAIN: **separation (splitting) into components // according to molecular size (mass, boiling point) / by distillation** (3 + 2)

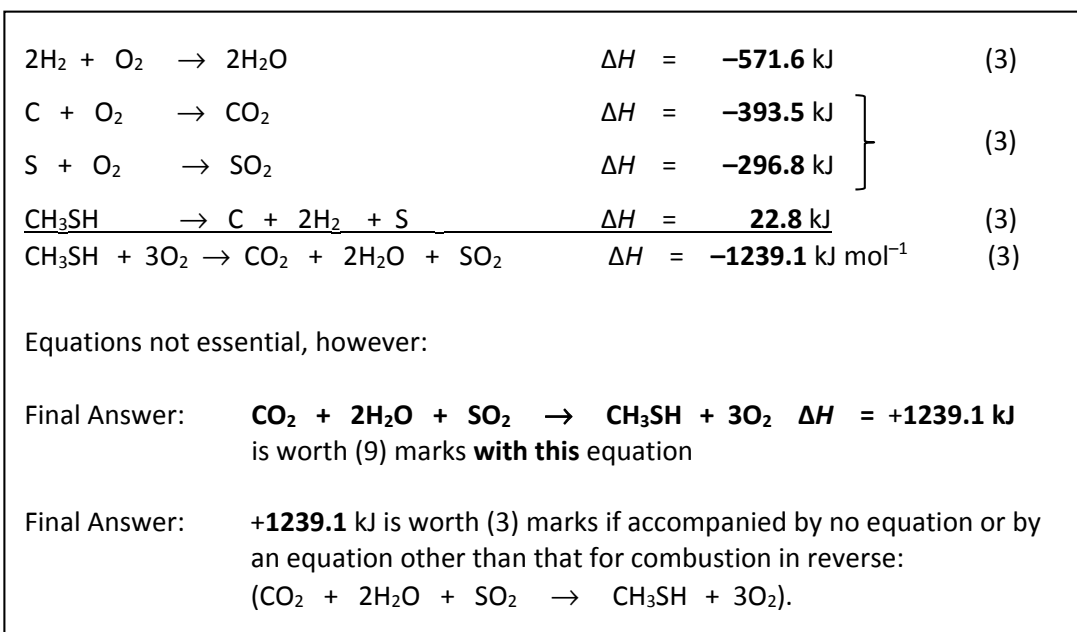
(b) (i) NAME: **propane // butane / methylpropane (2-methylpropane)** (2 × 3)

(ii) WHY: **to give a smell / to help detect leaks / safety** (3)

(iii) CALCULATE: **-1239.1 kJ mol⁻¹** (12)

$$\begin{aligned} \Delta H_{\text{combustion}} &= \Sigma \Delta H_{f(\text{products})} - \Sigma \Delta H_{f(\text{reactants})} \\ &= -571.6 \text{ kJ (3)} + [(-393.5) + (-296.8)] \text{ kJ (3)} - (-22.8 \text{ kJ (3)}) \\ \text{or} &= -571.6 \text{ kJ (3)} + [-393.5 - 296.8] \text{ kJ (3)} + 22.8 \text{ kJ (3)} \\ \text{or} &= -1261.9 \text{ kJ (6)} + 22.8 \text{ kJ (3)} \\ \text{and} &= -1239.1 \text{ kJ mol}^{-1} \quad (3) \\ &[+1239.1 \text{ by this method is not a slip and is worth maximum (9).}] \\ &[+1239.1 \text{ with no work shown is worth (3).}] \end{aligned}$$

or



(c) (i) GIVE: **2,2,4-trimethylpentane // butane // but-1-ene / 1-butene // ethylbenzene** (4 × 3)
[Allow 'phenylethane' for 'ethylbenzene'.][Do not accept 'iso-octane' for '2,2,4-trimethylpentane'.]
[Accept any order.]
[Cancellation applies to 5th substance **listed** excluding octane and hydrogen.]

- (ii) IDENTIFY: catalytic **cracking** // **dehydrocyclisation / reforming** (2 × 3)
[Take order of question unless responses clearly labelled; cancellation applies.]
- (iii) WHY: **increase (improve) octane rating (number, value) of a fuel / reduces tendency of fuel to cause knocking (pinking, autoignition, pre-ignition) / make more useful compounds (hydrocarbons) / make more fuel (compounds, hydrocarbons, molecules) of higher demand / increase value of products / make more efficient fuel / makes molecules (compounds, hydrocarbons) that are cyclic (shorter, more branched)** (3)
- (d) HOW: **diesel** has a **higher** boiling point / **petrol** has a **lower** boiling point (3)

QUESTION 7

- (a) (i) DEFINE: **change in concentration per unit (over, with) time** of one reactant (product) / **rate of change of concentration** of one reactant (product) / **change in concentration** / **time** of one reactant (product) (5)

or

$$\frac{\text{change in concentration of a reactant (product)}}{\text{time}} / \frac{d[\text{reactant}]}{dt} / \frac{-d[\text{reactant}]}{dt} / \frac{d[\text{product}]}{dt} \quad (5)$$

- (ii) WHAT: minimum combined **energy of colliding particles (molecules) // for reaction to take place** between them (2 × 3)
 or
 minimum combined **energy** of particles (molecules) // **for effective (successful) collisions**
 [At least one mention of collisions or colliding is essential.]

- (b) DRAW: **both axes correctly labelled concentration (M, M, mol l⁻¹) and time (t, s)** (3)
appropriate correct numeric scales on both axes (3)
careful plotting of points to give smooth curve of correct shape for NO₂ (6)
careful plotting of points to give smooth correct curve including origin for O₂ (6)

[For each curve deduct (3) for each of the following:
 poor curve due to inaccurate plotting of one or two points;
 all pairs of points connected with straight lines.]

[Deduct (6) marks for each of the following:
 different scales used for the two graphs;
 graphs not on graph paper;
 graphs on different sheets of paper;
 graphs side by side on same sheet of graph paper.]

[Time *versus* concentration graphs acceptable.]

- (c) FIND: **good tangent drawn at 100 seconds to NO₂ curve** (6)
 any two points correctly read from tangent, e.g. (0, 0.0087) and (205, 0.0040) /
 rise and run read from tangent, e.g. -0.0047, 205.

$$1.8 \times 10^{-5} \text{ to } 2.5 \times 10^{-5} \text{ M s}^{-1} \text{ NO}_2 \quad (3)$$

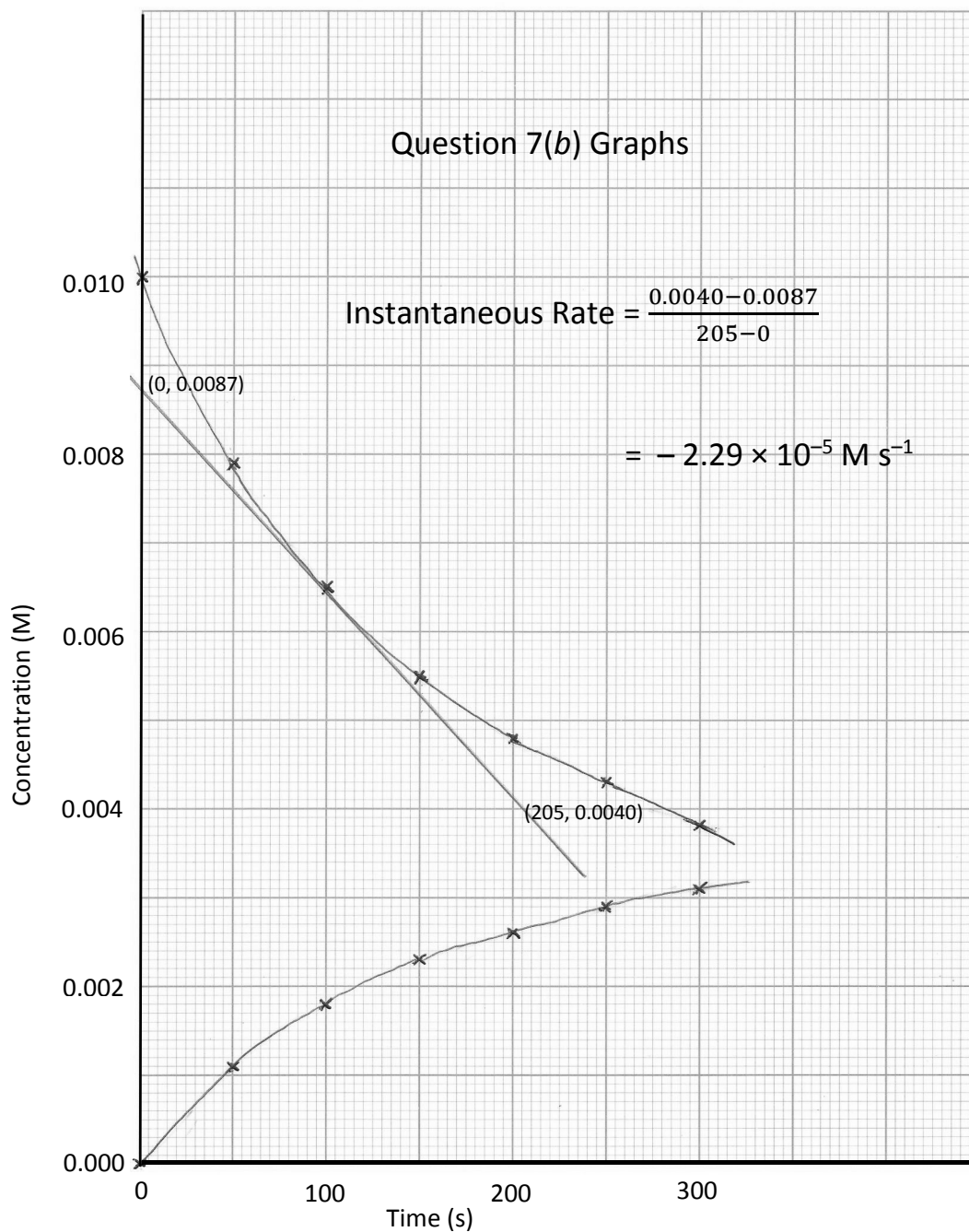
$\frac{0.0040 - 0.0087}{205 - 0} = \frac{-0.0047}{205} = -2.3 \times 10^{-5} \text{ } [-2.5 \times 10^{-5} \text{ to } -1.8 \times 10^{-5}] \text{ M s}^{-1} \text{ NO}_2 \quad (3)$

[Negative sign not required for rate.]

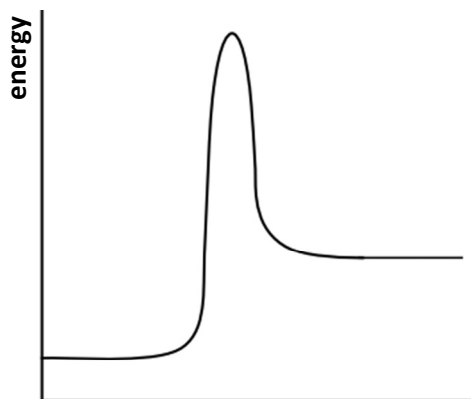
[Tangent must be drawn for work on rate to be awarded full marks;

(3) marks can be awarded for rate within stated range obtained from data table alone.]

[Last (3) marks is available consequentially for work done on a poor tangent drawn at 100 s to NO₂ curve or on any 'tangent' placed at incorrect time or on incorrect curve.]



- (d) (i) SUGGEST: molecules (particles, NO_2 , collisions) **did not possess activation (enough) energy** to break bonds / molecules (particles, NO_2 , collisions) **did not reach activation energy** / colliding molecules (particles, NO_2) were **not correctly orientated** for reaction (3)
- (ii) STATE: **increase the temperature (heat reaction mixture) / increase the concentration of NO_2 / increase the pressure** (3)
- (iii) SKETCH: **y-axis: energy** [Must be shown and labelled.]
x-axis [Must be shown but need not be labelled.] (3)
- suitable curve with energy of reactants less than energy of products** (3)
[Allow reactants drawn along x-axis.]



QUESTION 8

(a) (i) DRAW:

(2 × 3)

B	C
propan-1-ol	propanal
<pre> H H H H — C — C — C — O — H H H H </pre>	<pre> H H O // H — C — C — C — H H H </pre>
(3)	(3)

[ALL bonds, INCLUDING the bond between O and H in propan-1-ol, must be shown by separate strokes/lines.]

[Both alcohol and aldehyde functional group Hs MUST be explicitly shown.]

(ii) WHICH: **D / CH₃COOH/ ethanoic acid** (3)

(b) (i) EXPLAIN: *structural isomers:*
 compounds with **same molecular formula (molecules with same set (group) of atoms, molecules with same number of same atoms)** and //
different arrangement of atoms / compounds that have **different structures (structural formulae)** (2 × 3)

primary alcohol:

one (one or no) carbon (C) atom attached to carbon (C) to which the OH (functional group) is attached /

one (one or no) carbon (C) atom attached to hydroxyl carbon (C) (6)

or

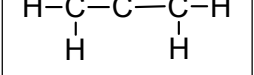
contains CH₂OH group / OH is attached to carbon (C) at the end of a chain / OH is attached to terminal (primary, last, end, outer) carbon (C) (6)

or

two (two or three) hydrogens (Hs) attached to carbon (C) to which the OH (functional group) is attached /

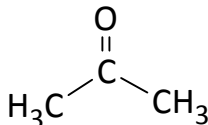
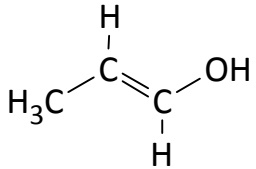
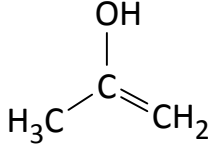
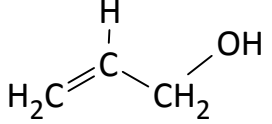
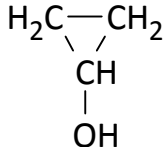
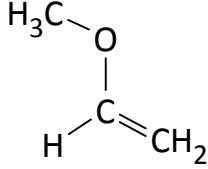
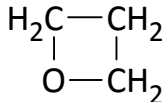
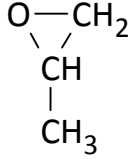
two (two or three) hydrogens (Hs) attached to hydroxyl carbon (C) (6)

[Allow (6) for 'OH is at end of chain'.]

(ii) DRAW: **CH₃COCH₃ / (CH₃)₂CO /**  **/ correct structure of another isomer** (3)

(iii) GIVE: **propan-2-one (propanone) / IUPAC name of drawn correct structural isomer of propanal (C₃H₆O)** (3)
 [DRAW and GIVE are linked.]

[Structural isomers of propanal are given on next page.]

Structural isomers of propanal		
Ketone	$\text{CH}_3\text{COCH}_3 /$ 	propan-2-one (propanone)
Alcohols (and enols)	$\text{CH}_3\text{CH}=\text{CH}(\text{OH}) /$ 	prop-1-en-1-ol / 1-propen-1-ol
	$\text{CH}_3\text{C}(\text{OH})=\text{CH}_2 /$ 	prop-1-en-2-ol / 1-propen-2-ol
	$\text{CH}_2=\text{CHCH}_2(\text{OH}) /$ 	prop-2-en-1-ol / 2-propen-1-ol
		cyclopropanol
Ethers		methoxyethene
		oxetane
		2-methyloxirane / methyloxirane

(c) EXPLAIN: (i) **propanal has dipole-dipole forces (bonds, interactions) /
propanal is polar /
propanal has a polar CO (bond, group) //**

**butane has weaker intermolecular forces (bonds, interactions) /
butane has weaker (van der Waals, London, dispersion) forces /
butane is non-polar**

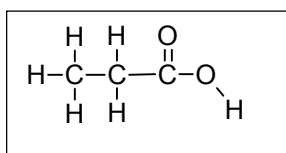
(2 × 3)

(ii) **ethanoic acid has more (stronger) hydrogen (H) bonding** than propan-1-ol
[Allow 'ethanoic acid has *double H-bonding*'.] /
propan-1-ol has less (weaker) hydrogen (H) bonding than ethanoic acid //
an ethanoic acid molecule **has polar OH and CO bonds (polar OH and CO groups) /
ethanoic acid has two polar groups //**
ethanoic acid **forms dimers //**
a **propan-1-ol** molecule only **has a polar OH bond (a polar OH group) /
propan-1-ol has only one polar group**
[Marks may be awarded for information given in good diagrams.]

ANY TWO: (2 × 3)

(d) WHAT: **propanoic (propionic) acid / CH₃CH₂COOH / C₂H₅COOH**

(6)



(e) WRITE: **C₃H₇OH + Na → C₃H₇ONa + ½H₂ / 2C₃H₇OH + 2Na → 2C₃H₇ONa + H₂ /**

**CH₃CH₂CH₂OH + Na → CH₃CH₂CH₂ONa + ½H₂ /
2CH₃CH₂CH₂OH + 2Na → 2CH₃CH₂CH₂ONa + H₂**

FORMULAE: (3) BALANCING: (2)

[Allow C₃H₈O for C₃H₇OH.]

QUESTION 9

(a) WHAT: **forward reaction and reverse reaction continue at equal rates / $r_r = r_f$ / $r_b = r_f$**
or
state reached at which **concentrations of reactants and products are constant** (5)

(b) WRITE: $K_c = \frac{[\text{COCl}_2]}{[\text{CO}][\text{Cl}_2]}$ (6)
[Square brackets essential.]

(c) (i) STATE & mixture becomes **less green / colour fades** (3)
[Allow '*mixture becomes colourless*'.]

EXPLAIN: higher pressure **favours (results in, produces) fewer moles (molecules)**
according to Le Chatelier's principle (3)

(ii) STATE & **smaller yield / less phosgene** (3)

EXPLAIN: higher temperature (heating) **favours (produces more)**
endothermic reaction (heat absorbing reaction) according to Le Chatelier's principle (3)

(iii) STATE & **no effect (none) /** [Allow '*only temperature changes affect K_c value*'.] (3)

EXPLAIN: **catalyst speeds up (affects, changes) both forward and reverse reactions equally /**
catalyst only affects time to reach equilibrium /
catalyst does not affect equilibrium concentrations (3)

[Accept any order of answering STATE and EXPLAIN in each of (i), (ii) and (iii) above.][Not linked.]

(d) CALCULATE: $K_c = (6800/3) 2266.67 - 2272 \text{ l mol}^{-1}$ (15)

	CO (g)	+	Cl₂ (g)	\rightleftharpoons	COCl₂ (g)	
Initially:	0.200 mol		0.200 mol		0 mol	
Change:	-x mol		-x mol		+x mol	
	x = 85% of 0.2 = 17/100 (0.17) mol					(3)
Equil:	0.2 - x mol		0.2 - x mol		+x mol	
	0.2 - 0.17 mol		0.2 - 0.17 mol		0.17 mol	
	3/100 (0.03) mol	and	3/100 (0.03) mol	and	17/100 (0.17) mol	(6)
	Divide by 12.0 before calculating K_c					
	1/400 (0.0025) mol/l	and	1/400 (0.0025) mol/l	and	17/1200 (0.014167) mol/l	(3)
$K_c =$	$\frac{[\text{COCl}_2]}{[\text{CO}][\text{Cl}_2]}$	=	$\frac{[0.014167]}{[0.0025][0.0025]}$	=	(6800/3) 2266.67 - 2272 l mol⁻¹	(3)

[Where (6) not awarded in box above, (3) is available for statement of ratio
-x mol : -x mol : +x mol]

or

	CO (g)	+	Cl₂ (g)	\rightleftharpoons	COCl₂ (g)	
Initially:	0.200 mol		0.200 mol		0 mol	
	Divide initial quantities by 12.0					
	1/60 (0.0167) mol/l	and	1/60 (0.0167) mol/l	and	0 mol/l	(3)
Change:	-x mol/l		-x mol/l		+x mol/l	
	x = 85.0% of 0.0167 = 17/1200 (0.014167)					(3)
Equil:	0.0167 - x mol/l		0.0167 - x mol/l		+x mol/l	
	0.0167 - 0.014167 mol/l		0.0167 - 0.014167 mol		0.014167 mol/l	
	3/1200 (0.0025) mol/l	and	3/1200 (0.0025) mol/l	and	17/1200 (0.014167) mol/l	(6)
$K_c =$	$\frac{[\text{COCl}_2]}{[\text{CO}][\text{Cl}_2]}$	=	$\frac{[0.014167]}{[0.0025][0.0025]}$	=	(6800/3) 2266.67 - 2272 l mol⁻¹	(3)

[Where (6) not awarded in box above, (3) is available for statement of ratio
-x mol/l : -x mol/l : +x mol/l]

[Do not allow mixing and matching of marks within boxes.]

[1 mark to be deducted for incorrect rounding off resulting in candidate's final answer lying outside given range.]

[Allow candidates to use incorrect K_c expression from (b) in last line of calculation without further penalty.]

- (e) SUGGEST: temperature too low gives **low rate (slow reaction)** / temperature low adds to **costs //**
pressure too high is **unsafe (costly)** (2 × 3)
[Allow (3) for 'cost increased' and (6) for 'both increase cost'.]
[Take order of question unless responses clearly labelled.]

QUESTION 10

- (a) DESCRIBE: **bubble (add, combine) ethene into (with) bromine water (solution) // red (brown, orange, yellow) bromine solution decolorised** (2 × 3)
- WOULD: **no** (3)
- EXPLAIN: **benzene is stable (quite unreactive, aromatic) / benzene has no double bonds / benzene bonds intermediate between double and single / benzene readily undergoes substitution** (3)
[WOULD and EXPLAIN are linked.]
- EXPLAIN: **shared between more than two atoms / shared by more than one bonded pair of atoms / moving (not fixed) between one pair of bonded atoms and another** (3)
[Allow 'shared by all six carbons atoms' and 'moving around ring (hexagon) of carbon atoms'.][Do not allow 'moving around whole molecule'.]
- HOW MANY: (i) **6** (3)
- (ii) **12** (3)
- WHAT: **carcinogen(ic) / causes cancer / mutagenic / breaks (damages) DNA (chromosomes) / toxic / harmful / dangerous** (4)
- (b) (i) WHAT: **ground state** (3)
- (ii) WHAT: **excited state(s)** (3)
- (iii) WHY: **it acquires energy / it is heated / an electric current passes through the gas / it is irradiated with light (electromagnetic energy) / absorbs a photon** (3)
- (iv) WHY: **higher energy states unstable** (3)
- (v) IDENTIFY: **$E_2 / n = 2 / \text{second}$** (3)
- HOW: **electrons have (exhibit) both wave // and particle properties** (2 × 2)
- or*
- electrons have (exhibit) wave // and particle duality** (2 × 2)
- or*
- electrons are tiny particles that also // have wave properties** (2 × 2)
- WHAT: **space (volume, region) around 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 (of) a Schrödinger wave equation** (2 × 3)

(c) (i) HOW MANY: **0.03** moles iron (6)

$$M_r \text{ iron phosphate} = \mathbf{151}^* \quad (3)$$

$$\frac{4.53}{151} = 0.03 \text{ moles iron phosphate} \quad \Rightarrow \quad \mathbf{0.03} \text{ moles iron} \quad (3)$$

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

[0.015 moles iron and 0.06 moles iron are contradictions and cancellation applies.]

(ii) WHAT MASS: **2.4** g iron oxide (rust) (9)

$$0.03 \div 2 = \mathbf{0.015} \text{ moles iron oxide (rust)} \quad (3)$$

$$M_r \text{ iron oxide} = \mathbf{160}^{**} \quad (3)$$

$$0.015 \times 160 = \mathbf{2.4} \text{ g} \quad (3)$$

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

(iii) WHAT: **5.0** cm³ phosphoric acid (6)

0.03 moles phosphoric acid

$$\frac{x \times 6.0}{1000} = \mathbf{0.03} \text{ moles} \quad (3)$$

$$x = \mathbf{5.0} \text{ cm}^3 \text{ phosphoric acid} \quad (3)$$

(iv) WHAT VOLUME: **0.81** cm³ water (4)

$$\mathbf{0.045} \text{ moles water} \quad (2)$$

$$0.045 \times 18^{***} \times 1.0 = \mathbf{0.81} \text{ cm}^3 \quad (2)$$

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

QUESTION 11

(a) (i) DEFINE: number expressing the **relative (measure of) attraction (affinity) of an atom // for shared pair(s) of electrons / for electrons in a covalent bond** (2 × 3)

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

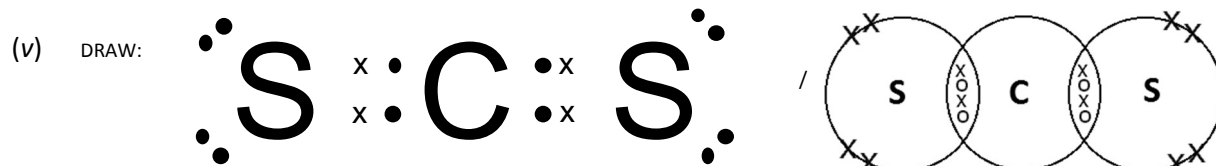
(iii) WHAT: **4 / IV** (3)

(iv) STATE: **tetrahedral //**
ACCOUNT: **four pairs electrons and no lone pairs** (2 × 3)

[Allow **four bonding pairs** of electrons only.]

[Marks available from correct diagram showing four bond pairs and no lone pair.]

[STATE and ACCOUNT linked.]



four correct shared pairs (4)

four correct lone pairs (3)

[Accept all dots or all crosses.][Ignore shape.]

(b) WHAT: substance that **dissociates into OH⁻ (hydroxyl ions, hydroxide ions) in water (aqueous solution) / substance that produces OH⁻ (hydroxyl ions, hydroxide ions) in water (aqueous solution) / substance that increases concentration of OH⁻ (hydroxyl ions, hydroxide ions) in aqueous solution** (3)

WHY: **NH₃ accepts a proton (H⁺)** (3)
[Allow 'ammonia (NH₃) accepts protons'.]

CALCULATE: (i) **pH = 0.30** (3)

$$\text{pH} = -\log [\text{H}^+] = -\log 0.50 = \mathbf{0.30} \quad (3)$$

[-0.3 loses this (3).]

(ii) **pH = 2.52** (6)

$$\text{pH} = -\log \sqrt{K_a [\text{HA}]} / \text{pH} = -\log \sqrt{1.8 \times 10^{-5} \times 0.50} \quad (3)$$

$$\text{pH} = \mathbf{2.52} \quad (3)$$

[-2.52 loses this (3).]

$$[\text{acid}] = [\text{HA}] = [\text{HX}] = M = M_a$$

WHICH : **ethanoic acid / CH₃COOH** (3)

STATE: **initial pH is 2.52 / starts at 2.52 / initial pH is not 0.30 / does not start at 0.3 //**
vertical part (steep rise) of graph is mostly above pH = 7 (between 7 and 11) //
buffering (no pH rise) between 12 and 35 cm³ NaOH added ANY TWO: (3 + 1)
[STATE marks only available if WHICH marks awarded.]

WHAT: **changes colour (pH range) between pH = 6 (7, 8) and pH = 9 (10, 11) / colour change (pH range of indicator) coincides with steep (vertical) part of graph / does not change colour before pH = 6 (7, 8)** (3)

(c) A (i) WRITE: $\text{MgCl}_2 + \text{Ca(OH)}_2 \rightarrow \text{Mg(OH)}_2 + \text{CaCl}_2$ FORMULAE: (3) BALANCING: (3)

$\text{Mg(OH)}_2 \rightarrow \text{MgO} + \text{H}_2\text{O}$ FORMULAE: (3) BALANCING: (3)
[Equations not linked.][Any order acceptable.]

WHAT: **refractory material / heat (high temperature) resistant material / fire-brick(s) / to line reaction vessels for steel industry / to line furnaces** (3)

IDENTIFY: **calcium chloride (CaCl₂)** (6)

STATE: **control noise / control dust / use electrostatic precipitators / control temperature (pH, suspended solids) of water returned to the sea / waste water pumped (taken) out to sea** (4)

or

(ii) IDENTIFY: **platinum and rhodium gauze / Pt & Rh** (3)

WHAT: **very exothermic / raises temperature helping to give fast economic rate of reaction (overcome activation energy) / supplies surplus energy to run plant (sell to grid) / causes costly catalyst breakdown (loss, vaporisation)** ANY TWO: (2 × 3)

WRITE: $\text{NO} + \frac{1}{2}\text{O}_2 \rightarrow \text{NO}_2 / 2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$ FORMULAE: (3) BALANCING: (3)

$3\text{NO}_2 + \text{H}_2\text{O} \rightarrow 2\text{HNO}_3 + \text{NO} /$
 $2\text{NO}_2 + \text{H}_2\text{O} + \frac{1}{2}\text{O}_2 \rightarrow 2\text{HNO}_3 / 4\text{NO}_2 + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{HNO}_3$
FORMULAE: (3) BALANCING: (3)

[Equations not linked.][Any order acceptable.]

EXPLAIN: **leaks result in acid-rain / damages trees (plants) / ammonia (NO, NO₂) corrosive (toxic, etc)** (4)

or

(iii) STATE: **500 °C (450 – 550 °C) / 773 K (723 – 823 K) // 200 atmospheres (50 – 350 atmospheres)** (2 × 3)

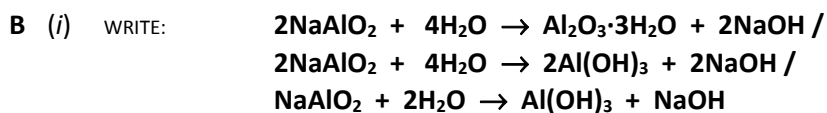
WHAT: **iron / Fe / magnetite (Fe₃O₄) / iron oxide / ruthenium (Ru)** (3)

WRITE: $\text{CH}_4 + \text{H}_2\text{O} \rightarrow 3\text{H}_2 + \text{CO} / \text{CO} + \text{H}_2\text{O} \rightarrow \text{H}_2 + \text{CO}_2 /$
 $\text{H}_2\text{O} \rightarrow$ by electrolysis $\text{H}_2 + \frac{1}{2}\text{O}_2 / 2\text{H}_2\text{O} \rightarrow$ by electrolysis $2\text{H}_2 + \text{O}_2$
FORMULAE: (3) BALANCING: (3)

EXPLAIN: **fractional distillation (fractionation) of liquid air / secondary reforming of methane (burning methane in air, removing combustion products to leave nitrogen)** (4)

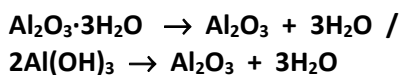
WRITE: $2\text{NH}_3 + \text{CO}_2 \rightarrow \text{NH}_2\text{CONH}_2 + \text{H}_2\text{O} /$
 $2\text{NH}_3 + \text{CO}_2 \rightarrow \text{NH}_2\text{COONH}_4$ and $\text{NH}_2\text{COONH}_4 \rightarrow \text{NH}_2\text{CONH}_2 + \text{H}_2\text{O}$
FORMULAE: (3) BALANCING: (3)

or



FORMULAE: (3) BALANCING: (3)

[Allow $\text{NaAl}(\text{OH})_4$ in balanced equation for NaAlO_2 .][Other versions also possible.]



FORMULAE: (3) BALANCING: (3)

[Equations not linked.][Any order acceptable.]

(ii) HOW: **electrolysis of molten alumina (electrolyte) //**
 $\text{Al}_2\text{O}_3 \rightarrow 2\text{Al} + 1\frac{1}{2}\text{O}_2$ ($2\text{Al}_2\text{O}_3 \rightarrow 4\text{Al} + 3\text{O}_2$) / $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$ //
carbon electrodes / anode replaced regularly as it is consumed by
oxygen co-product / temperature lowered by adding cryolite (Na_3AlF_6) /
any other relevant detail (3 × 3)

(iii) HOW: **use of hydroelectric power / use of cryolite**
[Allow recycling of aluminium.] (4)

