1. (a) (i) $Mr(C_6H_{11}OH) = 100$ **(1)**
$6.0 \div 100 = 0.06$ **(1)** 2

(ii) $Mr(C_6H_{10}) = 82$ **(1)**
Answer to (a)(i) $\times$ 82 **(1)** $= 0.06 \times 82 = 4.92$ g 2

(iii) $\frac{1.8}{\text{Answer to (a)(ii)}} \times 100\% = 36.6\%$ **(1)**
Consequential 1

(b) BP of cyclohexene is lower / BP of cyclohexanol is higher **(1)** so it distils off as it forms / comes over first / vaporises first / boils first / or details of method as to how the product could be distilled off first / cyclohexanol left behind **(1)** 2

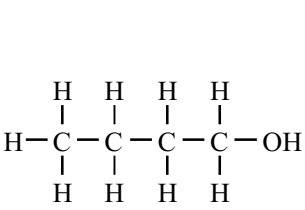
(c) Carbon must come from cyclohexanol so using it up / comes from competing reaction / idea of breakdown of reactants so that not all reactants converted to desired product **(1)**
1

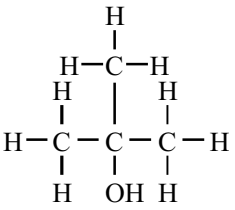
(d) Reference to taking care when adding water / add mixture to water **(1)**
Wearing gloves / safety goggles / safety spectacles **(1)** 2

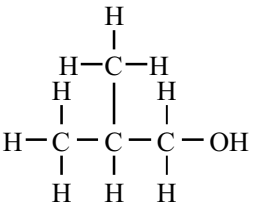
(e) Reagent: bromine (solution) / bromine water / Br_2
or potassium manganate(VII) + sulphuric acid / sodium carbonate / sodium hydroxide (or correct formulae) **(1)**
Result:
Br_2 yellow/red-brown/orange/orange-red/brown to colourless/decolourised/goes colourless *but not goes clear*
$KMnO_4$
purple to colourless/decolourised/goes colourless *not goes clear*
or if alkaline conditions brown ppt/solid **(1)** 2

[12]

2. (a) Diagrams:







Any two **(2)**

Names:
Butan-1-ol, (2)-methylpropan-1-ol,
(2)-methylpropan-2-ol any two **(2)** 4

(b) (i) From **orange to (blue-)green (1)** 1

(ii) butan-(2)-one **(1)**
Oxidation/redox **(1)** 2

[7]

3. (a) Mr 2-bromobutane = **137 (1)**
moles = 13.7/137 = **0.10 (1)** allow 0.1
moles KOH = 9.0156 = **0.16 (0.1607 or 0.161) (1)**
KOH present in excess consequential **(1)** 4

(b) Mr butan-2-ol **= 74 (1)**
max **moles** butan-2-ol obtainable = **0.10 (1)**
consequential on (a)
max mass = 0. 10 × 74 = **7.4 g (1)** answer **with units**
If candidate has calculated that the 2-bromobutane is in excess the calculation is based on 9 g of KOH, this gives 0. 16 mol of KOH and 11.9 g of product 3

(c) lone pair donor / electron pair donor / lone or electron pair can form co-ordinate / dative bond **(1)**
hydroxide ion / OH^- **(1)** 2

(d) rate increased **(1)**
C-I bond weaker (than C-Br bond) / lower bond energy **(1)** 2

[11]

4. (a) diagram 1 (heating under) reflux **(1)**
diagram 2 distillation **(1)** 2

(b) (i) reaction is slow / time needed for reaction to reach completion **(1)** 1

(ii) condenses vapours and returns liquid to flask / vapour turns to liquid and returns to flask **(1)**
(it allows reaction at boiling point of reactants) without loss / escape of material/reactants
prevents loss/escape of materials/reactants/products **(1)** 2

(c) heat the mixture (slowly) **(1)**
collect only fraction/distillate **(1)**
produced at 102 °C / around 102 °C / between 100-104 °C / at the boiling temperature of the 1-bromobutane **(1)**
Need to make clear that only distillate at this temperature is collected for second mark 3

(d) (i) $\frac{3.1}{7.2}$ **(1)** × 100 = 43.1 % **(1)** Allow 2-4 significant figures 2

(ii) two reasons from:
side reactions **(1)**
reaction incomplete **(1)** Max
product lost in purification / transfers **(1)** 2

[12]

5. (a) (i)

c	H	0	
68.2/12	13.6/1	18.2/16	÷ by A, **(1)**
5.68	13.6	1.14	÷ by smaller **(1)**
5	12	1	

formula $C_5H_{12}O$ **(1)**

(ii) Empirical formula mass = 88 = Molar mass **(1)**
Thus $C_5H_{12}O$ **(1)** 2

(b) (i) $ROH + PCl_5 \rightarrow RCI + HCl + POCl_3$ 2
(1) for HCl, **(1)** for the rest

(ii) Steamy / misty / fumes **(1)** 1

(c) (i) Any of
2-methylbutan-1-ol,
3-methylbutan-1-ol,
2,2-dimethylpropan-l-ol. **(2)** 2

(ii) Structure of the aldehyde consequent on the alcohol in (i) **(1)**
Mark CQ on the structure of the compound in (i), so if a 2° alcohol appears it must be a ketone, if a 3° alcohol no product or distils over. Carboxylic acid scores zero. 1

(iii) Potassium (or sodium or ammonium) dichromate(VI) **(1)**
and sulphuric acid **(1)**
Potassium manganate(VII) **(1)** <u>dilute</u> sulphuric acid **(1)** 2

(iv) Carboxylic acid **(1)** *Consequential* 1

(d) (i) C=C **(1)**
or 1
Correct structure from Z with double bond shown **(1)**

(ii) Carbon skeleton derivable from the structure of the alcohol used in (c)(i) **(1)**
two bromine in correct places from that alkene **(1)**
Note:
if 2, 2-dimethylpropan-1-ol given in c (ii) can have 2 marks for any sensible chemistry based on this 2

[17]

6. (a) (i) Free radical **(1)** 1

(ii) Ethane single bonds / σ only **(1)**
- C-H must be broken **(1)** could be awarded for explained reference to difficult to break

Ethene **also** has π bond / σ and π bonds **(1)**
where electrons are more accessible/ π bond is weaker(and breaks) **(1)** 4

(b) (i) 1-bromopropane **(1)** 1

(ii) $CH_3CH{=}CH_2$ **(1)** 1

(iii) $CH_3CH_2CH_2OH$ **(1)**. 1

(iv) Nucleophile **(1)**. 1

(v)
- C-Cl bond is stronger than C-Br **(1)**
- so activation energy for reaction is higher /more kinetically stable **(1)** (in the case of the chloro- compound). 2

[11]

7. (a)
- Apparatus to show round or pear shaped flask **(1)** not conical
- Reflux condenser - *must have inner tube and inlet and outlet for water* **(1)**

Controlled source of heating e.g. electric heater/ hot plate **(1)**
Reasonable drawing **(1)** of an apparatus that would work. 4
Eg not sealed apparatus, water must flow correctly through condenser, joint shown between flask and condenser (no obvious gaps), no extras
*Show as ✓ **Q** on the script for this mark*

(b) (i) (Fractional) distillation

(ii) The mixture may be separated because the boiling temperatures are different / 1-bromobutane has lower boiling temperature (than butan-1-ol) **(1)**
The 1-bromobutane will distil over / vaporise first (and can be collected) **(1)**
allow butan-1-ol is left in the flask 2

(c) (i) Mr = 74 **(1)**
11.1/Mr = correct answer **(1)** [0.150 mol] 2

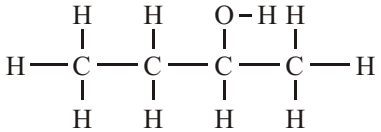
(ii) Mr = 137 **(1)**
Answer to (i) × Mr = correct answer **(1)** [20.55 g] 2

(iii) $\frac{12.4 \times 100}{\text{answer to (ii)}}$ = correct answer [60.3 or 60.2] **(1)** 1

(iv) Any **one** of:
- competing reactions
- side reactions
- incomplete reaction
- product lost in purification
- product lost in transfers. 1

[13]

8. (a)



OH on second carbon atom **(1)**

All of molecule displayed **(1)**

Butan-2-ol **(1)** 3

(b) (i) $CH_3CH_2CH_2CH_2OH$ *OR* $CH_3CH(CH_3)CH_2OH$ OR CH_3CHCH_2OH (CH$_3$ below CHCH$_2$OH)

NOT displayed

NOT C_4H_9OH 1

(ii) Butanone **(1)**
Butanal and butanoic acid *OR*
2-methylpropanal and 2-methylpropanoic acid **(2)**
IF Ketone, Aldehyde + Carboxylic acid **1 (out of 3)** 3

(c) (i) Suitable flask with contents and heat **(1)**
Vertical Liebig condenser **(1)**
Water flow correct **(1)** 3

IF distillation and correctly drawn **1 max** *ie for flask and heat*

Penalties

Poor diagram **–1**

Sealed apparatus **–1**

(ii) (Fractional) distillation 1

(d) (i) $CH_3CH=CHCH_3$ or $CH_3CHCHCH_3$ **(1)**

ALLOW cis and trans forms for 2 marks

ALLOW displayed

$CH_3CH_2CH=CH_2$ **(1)**

But-2-ene and but-1-ene or cis-but-2-ene and trans-but-2-ene **(1)** 3

(ii) purple/(pale) pink to colourless/brown 1

(iii) Bromine (water) *NOT* bromine gas 1

[16]

9. (a) It is a mixture / not a single compound 1

(b) (i) 2,4-dimethylpentane 1

(ii) C_7H_{16} 1

(iii) More volatile / lower boiling point / vaporises more readily / branched so doesn't knock / higher octane number 1

(iv) Heat / high temperature / ≥ 200 °C **(1)**
Silica / alumina (catalyst) /zeolites **(1)** 2

(v) *Diagram should show:*

Test tube containing paraffin absorbed on suitable absorbent – **(1)**
absorbent can be just shown in the diagram

Aluminium oxide catalyst **(1)**
Heat catalyst **(1)**
Recognition of collection of gas over water /gas syringe **(1)** 4

Penalties
–1 for poor diagram

(c) (i) $(CH_3)_2C = CH_2$
ACCEPT $(CH_3)_2CCH_2$ 1

(ii) Elimination 1

(iii) Potassium hydroxide / KOH / NAQH **(1)**
Ethanolic / alcoholic solution + heat / reflux **(1)** 2

[14]

10. (a)
- A species with a lone pair / pair of electrons **(1)**
NOT "negative ion" alone or as an alternative
- which it uses / donates to form a (dative) covalent bond **(1)** 2

(b) (i)
- Ammonia / NH_3 (in ethanol) **(1)**
- heat **(1) NOT** heat under reflux *UNLESS* in a sealed tube

If a temperature is quoted it must be greater than 100°C

- in sealed tube / under pressure / concentrated **(1)**

If a pressure is quoted it must be greater than 1 atm

Conditions are dependent on correct reagent.

If ammonia and an additional reagent **max (1)** for two correct conditions. 3

(ii) Carbon-bromine bond stronger / higher bond enthalpy than
carbon – iodine / Ea for C-Br is higher than C-I

IGNORE any extra explanations involving the alkyl groups 1

(c) Identify bonds broken **and** made **(1)**

e.g. Energy in + 464 or + 3340

AND Energy out (-) 656 or (-) 3532 **(1)**

Energy needed to break bonds – energy released to make bonds = 36 **(1)**

e.g. C-I + 464 – 656 = + 36

or C-I + 3340 – 3532 = + 36 **(1)**

Correct evaluation dependent on use of 36 **(1)**

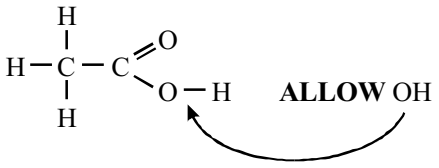
i.e. C-I = 228 kJ mol^{-1} **(1)**

Correct answer with some correct working **(3)**

If final answer is negative max **(2)**

If 36 is on the wrong side, then 156 max 2 (-156 **(1)**)

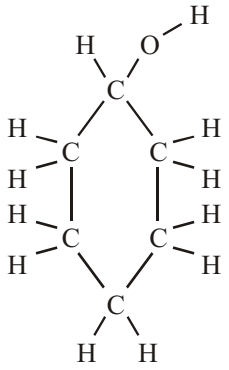
If miss out 36, then ±192 **max 1** 3

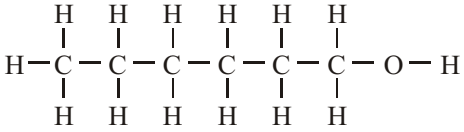
(d) 

1

[10]

11. (a) (i) All bonds and atoms shown for each alcohol 2





(ii) Molecular formulae are different / different number of hydrogen atoms in each 1

(iii) cyclohexanol secondary **(1)**
hexan-1-ol primary **(1)** 2

(iv) $CH_3CH_2CH_2CH_2CH_2CHO$ **(1)**
Hexanal **(1)** 2

(v) Warm with Benedict's / Fehling's solution **(1)**
Hexan-l-ol: blue solution goes brown / red-brown / red / orange / yellow/ green (ppt) **(1)**
Cyclohexanol: no change/ stays blue **(1)**
Use of bromine to test for an alkene **(0)**
Use of sodium carbonate to distinguish hexanoic acid from cyclohexanone, described correctly **(3)**
OR test with suitable acidified dichromate
OR manganate(VII)
Product of hexan-1-ol: orange → green with dichromate
purple → colourless with permanganate
Product of cyclohexanol: no change 3

(b) (i) Elimination/ dehydration 1

(ii) Labelling not required if apparatus recognisable
Round-bottom / pear-shaped flask + heat **(1)**
cyclohexanol + conc sulphuric acid / phosphoric acid **(1)**
condenser with correct water flow **(1)**
receiving vessel OR closed flask + vent **(1)**
OR tube containing mineral wool + heat
(heat left hand side of tube) **(1)**
Cyclohexanol in wool + aluminium oxide / Al_2O_3 **(1)**
Penalties
Apparatus would not work e.g. no stopper above flask –1
Poor diagram –1
Completely sealed apparatus –1 4

(iii) Add anhydrous/fused calcium chloride or anhydrous sodium / magnesium sulphate
Accept formula
Decant / filter off drying agent **(1)**
For (re-)distilling without mentioning drying agent
Accept fractional distillation **(1)** 2

[17]

12. (a) (i) Two reactants form **one product** 1

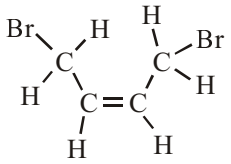
(ii) **Substitution** reactions occur under these conditions 1

(iii) The electrons of the double / π bond polarise the Br – Br molecule **(1)**

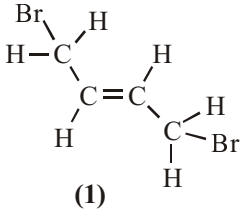
and Br $^{\delta+}$ is the electrophile **(1)**

OR show Br $^{\delta+}$ *– Br* $^{\delta-}$ *attacking in the correct orientation* 2

(b) (i)



(1)

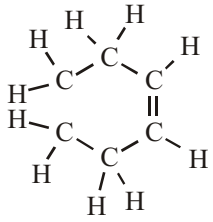


(1) 2

(ii) No rotation about a C =C double bond

OR only single bonds can rotate 1

(c) (i)



1

(ii) Low temperature because exothermic reaction **(1)**

High pressure because fewer molecules of product than of reactants gases are being converted into liquids **(1)** 2

[10]

13. (a) (i) 1,2-dichloroethane 1

(ii) $CH_2 = CHCl$ / CH_2CHCl 1

(iii) e.g. dissolve / bubble HCl in water / absorb in an alkali / condense the HCl(g) 1

(b) (i) Species having unpaired electron 1

(ii) Action of UV radiation/sunlight / named initiator / photoflood 1

(c) (i) Water / OH^- 1

(ii) Unshared / lone pair of electrons on a legitimate nucleophile based on (c)(i) **(1)**

(c)(i) "nucleophile" attacks / forms bond with **C** of C – Cl **(1)** 2

(iii) Chloride ion / Cl^- 1

(iv) Add silver nitrate solution **(1)**
white ppt **(1)** 2

[11]

14. (a) (i) Electron pair/ lone pair acceptor
Or accepts electrons to form a (dative) covalent bond 1

(ii) Particle with an unpaired electron 1

(iii) Electron pair/ lone pair donor
Or donates electrons to form a (dative) covalent bond 1

(b) (i) Nucleophilic **(1)**
Substitution **(1)** 2

(ii) (Free) radical **(1)**
Substitution **(1)** 2

(iii) Electrophilic **(1)**
Addition **(1)** 2

[9]

15. (a) (Heating under) reflux **(1)**
Distillation/simple distillation **(1)**
NOT fractional distillation 2

(b) (i) $\frac{137}{74} \times 3.70$ **(1)** = 6.9/6.85(g) **(1)** 2

(ii) $\frac{4.60}{\text{answer to (i)}} \times 100 = 67 / 66.67 / 66.7\ \%$ 1

(iii) Slow/reaction takes a long time / high activation energy. 1

(iv) Measure boiling temperature/point **(1)**
Compare with data book/literature/known value **(1)** 2

(c) (i) Orange to green 1

(ii) **Oxidation** continues **(1)**
carboxylic acid formed **(1)** 2

(iii) Aldehyde/first product distilled off as it forms/removed from reaction mixture 1

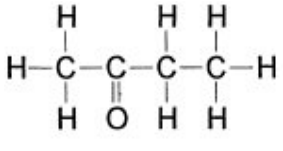
[12]

16. (a) $C_4H_{10}O + Na \rightarrow C_4H_9O^{(-)}Na^{(+)} + ½ H_2$
entities **(1)**
balancing, ignoring charges in organic product **(1)** 2

(b) (i) Cr^{3+} 1

(ii) Heat and round-bottom (suitable i.e. not a beaker) flask **(1)**
condenser above **(1)**
water jacket and water direction
ALLOW arrows for water direction **(1)**
–1 poor diagram e.g. flask and condenser integrated
–1 sealed apparatus 3

(iii)



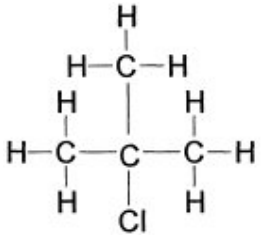
(1) **(1)**

Butanone / butan-2-one **(1)** 2

(iv) $CH_3CHOHCH_2CH_3$
ALLOW TE from (iii) for butanal / butanoic acid 1

[9]

17. (a)



(1)

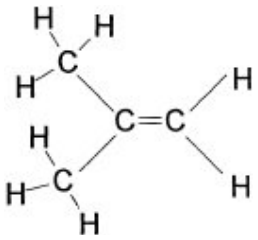
2-chloro-2-methylpropane **(1)**

No marks for primary or secondary halogenoalkane even if both formula and name are consistent
Must be displayed 2

(b) (i) Hydrogen chloride
OR HCl
OR (concentrated) hydrochloric acid *NOT* **dilute** hydrochloric acid
OR sodium / potassium chloride and concentrated sulphuric acid/ phosphoric acid 1

(ii) Substitution **(1)**
Nucleophilic **(1)** 2

(c) (i)

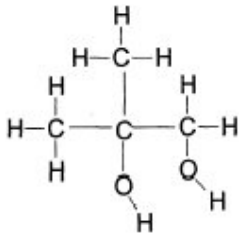


2-methylprop-1-ene 2

(ii) No because each carbon atom joined by the double bond has the same two groups attached to it/ OWTTE 1

(d) Reduction / addition hydrogenation **(1)**
Oxidation / addition **(1)** 2

(e)



Must be consistent with (c)(i)
Must be displayed 1

[11]

18. (i) nucleophilic substitution **(1)** 2
aqueous **(1)** Ignore heat under reflux here
Allow aqueous ethanol

(ii) elimination **(1)**
ethanolic / alcoholic **(1)**
heat (under reflux) **(1)** not h.u.r. , not warm 3

[5]

19. (a) Potassium / sodium dichromate(VI)/$K_2Cr_2O_7$/$Na_2Cr_2O_7$
Allow potassium manganate(VII)/permanganate/$KMnO_4$/potassium chromate /K_2CrO_4 1

(b) (i) Exothermic 1

(ii) (Cold) **water moving** through the condenser/water cools the vapour 1

(iii) To prevent **ethanal** vaporising / **ethanal** is volatile 1

(iv) (Remove ethanal) because fumes/vapour/gas flammable/irritant/harmful, **not** *toxic* 1

(c) $\frac{44}{46} \times 5.0$ **(1)** $= 4.8$ g

$4.8 \times \frac{40}{100} = 1.9$ g **(1)**

The second mark can be scored if candidates make use of 2 M_r values, 5.0g and 40% and the answer is less than 5.0g. 2

[7]

20. (a) (i) Solvent/to allow mixing/dissolving 1

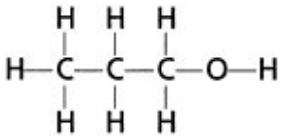
(ii) $Ag^+(aq) + X^-(aq) \rightarrow AgX(s)$ allow Cl^-, Br^- or I^- formulae **(1)**
state symbols **(1)** allow state symbols if NO_3^- is in the equation. 2

(iii) Ethanol/halogenoalkanes flammable / constant temperature/controlled temperature. 1

QWC (b) Equal volumes/amounts/quantities of ethanol / silver nitrate **(1)** **(1)** V
Equal moles/amounts (not volumes) of halogenoalkanes **(1)** **(1)** A
Test tubes reach temperature of water bath before mixing. **(1)** **(1)** E
Mix reagents simultaneously / start timing on addition of reagents **(1)** **(1)** T
Any two of white, cream, yellow (precipitates) **(1)** **(1)** C
Iodide forms first then bromide then chloride / shortest time **not** rate **(1)** **(1)** O
If any additional reagents are added. **Max 4** MAX 5

[9]

21. (a) (i)



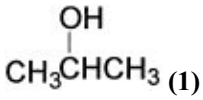
1

(ii) Diagram should show
Test tube containing propan-1-ol absorbed on suitable named absorbent **(1)**
Aluminium oxide/porous pot catalyst named **(1)**
Heat source **below** catalyst **(1)**
Collection of propene gas over water / gas syringe **(1)** 4
Penalise –1 for poor diagram/wouldn't work

(b) (i) Sodium propoxide 1

(ii) 0.002 mol/ 2×10^{-3} mol 1

(c) (i) $CH_3CH(OH)CH_3$ *OR*



(1)

Propan-2-ol **(1)** 2

(ii) Propanal - from blue to red/green/orange/brown ppt **(1)**
Propanone - no change/stays blue **(1)**
'blue' must be mentioned as the initial colour at least once. 2

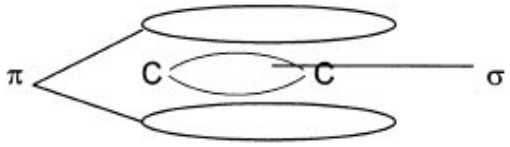
[11]

22. (a) (i) $C_2H_6(g)/(l) \rightarrow C_2H_4(g) + H_2(g)$
If a state symbol is missing **(0)**

If (aq) **(0)** 1

(ii) At high pressure reaction goes in direction to reduce pressure/to oppose change by Le Chatelier's principle **(1)**
towards side with fewer molecules/moles **(1)** 2

(b) Shapes of orbitals between and above carbon



If p orbitals drawn msut show overlapping

Shapes **(1)** ACCEPT crescents for π bonds NOT lines for σ bond 2
Labels **(1)**

(c) Addition of bromine **water/solution (1)**
from yellow/brown/orange to **colourless (1)**
OR
acidified potassium manganate(VII) **(1)**
from pink/purple to **colourless (1)** 2

(d) Addition **(1)**
Elecrophilic/electrophile *OR* appropriate *explanation* **(1)** 2

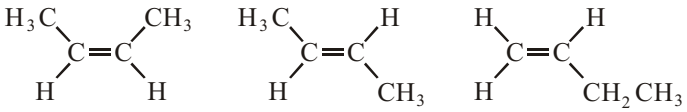
[9]

23. (a) (i) $CH_3CHICH_2CH_3$ /$CH_3CHIC_2H_5$ **(1)**
(allow full structural formula) 1

(ii) Reagent: sodium hydroxide/potassium hydroxide **(1)**
Condition: aqueous (ethanolic) solution **(1)**
dependent on correct reagent 2

(iii) (Heat) in ethanolic solution /ethanol/ alcohol **(1)** 1

(iv)



(1) **(1)** **(1)** 3

$CH_3CH{=}CH\ CH_3$ and $CH_2{=}CH\ CH_2CH_3$ **max 2**

(b) Rate bromo would be slower **(1)** (or reverse argument)
as C–Br bond is stronger (than C– I) **(1)**
consequential on correct 1st point
and so activation energy would be greater **(1)**
consequential on their answer to 1st point 3

[10]

24. (a) (i) $\frac{137}{74} \times 4.0 = 7.4 / 7.41$ g 7.40 g is an s.f. error
2 or 3 SF 1

(ii) $5.9 \times 100 = 80$ %
ALLOW 79.7 / 79.6
conseq on (a) (i)
2 or 3 SF 1

(b) (i) (Turns hot) <u>vapour</u> into liquid / condenses **(1)**
NOT just 'cooled'
NOT just 'product vapour'
Which returns to reaction mixture / allows reaction to go to completion / minimises loss of reactants or products **(1)** 2

(ii) Two layers shown and upper layer is water 1

(iii) To dry (1-bromobutane) / as a drying agent
NOT 'to prevent reaction with 1-bromobutane' 1

(iv)
- Heated flask (round or pear shaped ONLY) **(1)**
- Condenser **(1)**
- Thermometer <u>in correct position</u> **(1)**
- Quality – workable and safe **(1)**^{Q} **(1)**

(NOT scored if:
wrong direction of water flow in condenser
gaps in apparatus
sealed apparatus
delivery tube in product
no joints whatsoever
condenser not sloping downwards
water bath used for heating 4

(c) Wear gloves, 1-bromobutane harmful (by skin absorption)
NOT 'corrosive' *NOT* 'irritant'
H_2SO_4 is corrosive *NOT* 'irritant'
Electrical heater / heating mantle, 1-bromobutane flammable
Fume cupboard, 1-bromobutane harmful (vapour) *NOT* 'irritant' 1

[11]

25. (a) Isomer(s) 1

(b) B and C 1

(c) A 1

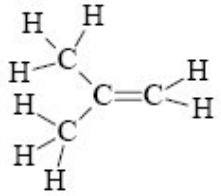
(d) 2-methylpropan-2-ol 1

(e) D and E 2

(f) (i) Removal of water 1

(ii) Alkene / C=C /carbon carbon double bond 1

(iii)



(1)

(1)

2-methylprop-1-ene **(1)**

[10]

26. (a) Van der Waals/induced dipole-dipole 1

(b) (i) Hydrogen/dipole-dipole in **propan-1-ol**,(but no hydrogen/ dipole-dipole in butane) 1

(ii) Van der Waals forces in propan-1-ol are stronger
OR reverse argument **(1)**
because chain is not branched/so more surface contact between molecules)
OR reverse argument **(1)** 2

[4]

27. (a) (Sweat is a dilute aqueous) solution of sodium chloride and urea,
(and also other metabolic waste products, such as the lactates produced in muscles)
OR
Is a mixture of water, sodium chloride, urea 1

(b) (Sweat is produced by the eccrine glands) via emotional, thermal and sensory stimuli 1

(c) $CH_3CH_2CH_2CH(CH_3)CH_2COOH$
correct answer **(2)**
correct structure, except CH_3 branch in wrong place **(1)**
structure for a methylheptanoic acid **(1)** 2

(d) Antiperspirants were too acidic and irritated the skin/rotted clothes 1

(e) $Al_2(OH)_2Cl_4$ 1

(f) e.g. more wasted using aerosol
application more precise with roll-on/ consequences for atmospheric pollution using aerosols/any other feasible alternative
ACCEPT environmental pollution + *qualification* 1

[7]

Word total/penalty

Candidates should have recorded their word total at the end of their answer, and this should be checked.

up to 105 words: no penalty
106 – 115 words: –1
116 – 125 words: –2
126 – 135 words: –3

and at a rate of –1 penalty for every 5 words excess thereafter, up to a maximum penalty equal to the number of key points included by the answer.

Note that words appearing in the title to the summary do not count in the word total. Normally hyphenated words (such as odour-causing, roll-ons, mid-1970s, zinc-based), numbers and chemical formulae count as one word. The question does not ask for equations in the summary, but if included they should be counted in the word total.

99 %	= 2 words
RCOOH	= 2 words
BO	= 2 words
$Al_2(OH)_mCl_n$	= 2 words
ACH	= 2 words
1947	= 2 words
$C_4 – C_{10}$	= 3 words
m+n = 6	= 3 words

Marking for key points (6 marks)

One mark should be awarded for every key point clearly identified in an answer, up to a maximum of 6 marks.

A tick should be made in the script. Examiners should show the key point being awarded, i.e. ✓[3] shows key point 3 given.

List of key points: these may be in a different order, and need not be expressed in the wording below provided that the sense of each point is conveyed.

Key pt

Distinction

✓[1] Deodorants act (solely) to reduce BO by **killing** / **eradicating** / **destroying** the (odour-causing) bacteria. **(1)**

✓[2] Antiperspirants reduce both odour **and** wetness
OR
In addition antiperspirants reduce wetness - *dependent on* key *pt 1* **(1)**

✓[3] Ethanol is the **principal** antibacterial agent **(1)**

✓[4] with **further activity** [OWTTE] derived from some of the added perfume oils.**(1)**

✓[5] Aluminium **salts** are (commonly) used in antiperspirants (nowadays).....
NOT aluminium chlorohydrates **(1)**

✓[6] ..... and these **physically** block the eccrine/sweat glands - *must follow on from "aluminium"* **(1)** 4

Formulation

✓[7] Deodorants and antiperspirants can be sold as a solution, a suspension or emulsion **(1)**

Application

✓[8] and can be applied in)
pump sprays)
roll-ons) *Any two* **(1)**
sticks)
aerosols)
gels)

2

Quality of Written Communication (2 marks)

These should *be impression* marked on a scale 2-1-0, and the mark out of 2 should be recorded in the body of the script at the end of the answer. This mark can not be lost as a result of a word penalty.

Candidates are expected to:

- show clarity of expression;
- construct and present coherent argument;
- demonstrate effective use of grammar punctuation and spelling.

The aspects to be considered are:

- use of technical terms; the answer should convey a correct understanding by the writer of the technical terms used in the passage which are involved in the key points.

- articulate expression; the answer should be well-organised in clear, concise English, without ambiguity. It should read fluently, with the links between key points in the original maintained.
- legible handwriting; the reader should be able to read the answer without difficulty at normal reading pace, with only the occasional difficulty with a word.
- points must be in a logical order.

Good style and use of English, with only infrequent minor faults, no use of formulae **(2)**

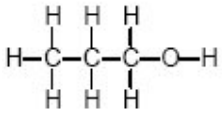
Frequent minor or a few major faults in style and use of English **(1)**

Very poor style and use of English **(0)**

[15]

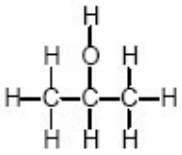
28. (a) (i)

Isomer 1



(1)

Isomer 2



(1)

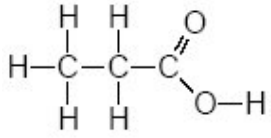
propan-1-ol /1-propanol **(1)** propan-2-ol / 2-propanol **(1)** 4

NOT propanol

ALLOW –OH

Penalise sticks once : penalise CH_3 once

(ii)



(1)

ALLOW CH_3CH_2 and C_2H_5 but not COOH 2

Colour change orange to green / blue / brown **(1)**

(b) (i) **<u>PBr_5 / PBr_3 / red phosphorus + Br_2</u>**
<u>or</u>
<u>sodium/potassium bromide and (conc) H_2SO_4 /50% sulphuric acid/ (conc) phosphoric acid / KBr + H_2SO_4</u>

NOT dilute 1

(ii) 2- bromopropane / $CH_3CHBrCH_3$ *NOT* Bromo-2-propane 1

(iii) **$\underline{CH_3CH(OH)CH_3}$ (1)**

$CH_3CH=CH_2$ must show double bond **(1)**
ACCEPT full structural formulae **(1)**
*ALLOW T.E. based on **X*** If 1-bromopropane 2

[10]

29. (a) (i) 1-chloropropane has more electrons than chloroethane **(1)**

So van der Waals' forces (between molecules) stronger/greater
OR
More/greater van der Waals' forces **(1)**

OR reverse argument

If dipoles are mentioned they must be temporary /induced / transient / fluctuating / flickering 2

(ii) Molecules in 2-chloropropane make less contact / pack less well / can get closer together OWTTE

ACCEPT annotated diagram

If the explanation about van der Waals' forces is given here allow it in (i) UNLESS incorrect intermolecular force mentioned in (i) 1

(b) (i) Reagent with a lone pair of electrons
OR
Pair of electrons which it can use to make a bond
OR
Reagent which attacks species with a (δ) + charge

NOT "attacks nucleus" *on its own*
NOT "species with a negative charge" 1

(ii) C-l bond is weaker than C-Cl
Must say which bond is weaker 1

(c) (i) Use ethanolic KOH/KOH in alcohol/KOH in ethanol/ ethanol as solvent (and raise temperature) 1

(ii) Elimination **(1)**
IGNORE comment on what is eliminated
IGNORE qualification eg electrophilic 1

[7]

30. (a) (i) Reaction takes time
OR reaction is slow / activation energy is high
OR to speed up the reaction / supplies activation energy
Answer could be covered in (ii) allow mark provided the answer in (i) is sensible. 1

(ii) (Without a reflux condenser the volatile)
substances / the ester could be boiled off. 1

(b) Any flask and any source of heat **(1)**
ALLOW "Heat"
Flask must be connected to the rest of the apparatus
ALLOW flask & condenser as one piece of apparatus

vertical condenser **(1)**
water flow **(1)** consequential on a vertical condenser
apparatus not closed **(1)** consequential on a vertical condenser 4

(c) (i) To convert it into benzoic acid
OR to liberate the acid (from the salt)
OR a description of the chemistry 1

(ii) Because the acid is soluble in hot water
OR the acid is insoluble in cold water
OR to crystallise out the acid 1

(d) (i) Amount of ester = 4.5 ÷150 = 0.03 (mol) **(1)**
Amount of product = 2.93 ÷122 = 0.024 (mol) **(1)**

$$\% \text{ yield} = \frac{0.024 \times 100}{0.03} = 80\% \quad \textbf{(1)}$$

OR

150 g ester ⇒ 122 g acid **(1)** 4.5 g $\Rightarrow \frac{4.5 \times 1.27}{150} = 3.66$ g **(1)**

$$\frac{2.93 \times 100}{3.66} = 80\ \% \quad \textbf{(1)}$$

$$\frac{\frac{2.93}{4.5} \times 100}{} \quad \textbf{(0)}$$ 3

(ii) Lowered because more stays in solution
OR Lowered because some stays in solution 1

(e) PCl_5 reacts with water 1

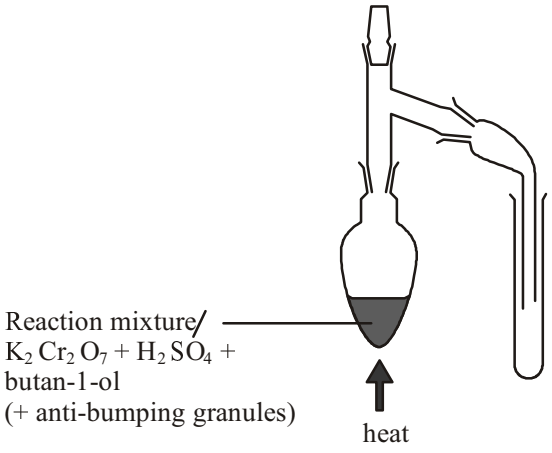
[13]

31. (a) (i) Redox
ALLOW oxidation / partial oxidation
NOT reduction / complete oxidation 1

(ii) Sodium or potassium dichromate ((VI)) / $Na_2Cr_2O_7$ / $K_2Cr_2O_7$ **(1)**
Sulphuric acid / H_2SO_4 dilute or concentrated **(1)**
IGNORE any Roman numerals
ALLOW H^+ and $Cr_2O_7^{2-}$ / acidified dichromate **1 (out of 2)**
H_2SO_4 mark not allowed if mixed with an alkali/carbonate 2

(iii) Orange to green / blue / blue green
ALLOW TE of purple to colourless / brown if MnO_4^- used in ii 1

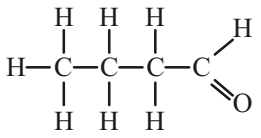
(iv)



Arrow is enough to show heat

Pear-shaped/round bottomed flask/tube with side arm + reagents/reaction mixture + heat **(1)**
Side-arm from adaptor/delivery tube from side-arm tube/condenser + collecting vessel **(1)**
–1 for poor drawing eg line not tube, sealed apparatus, open at top, collecting under water, large gaps in equipment, one-piece equipment (ie flask must be separate from rest)
IF condenser used ignore water direction
No marks if refluxed/apparatus would not work 2

(v)



1

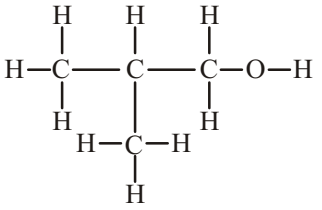
Watch for  **(0)**

(vi) Benedict's solution (+ heat + NaOH) **(1)**
Red/brick-red (precipitate) **(1)**
ALLOW green/yellow/brown/red-brown/orange
Stays blue (solution) **(1)**
ALLOW nothing happens / no change if Benedicts colour given earlier

OR

potassium/sodium dichromate + acid **(1)**
goes green **(1)** ALLOW goes blue
stays orange solution **(1)**
ALLOW correct results with Fehlings solution or Tollens reagent 3

(b)



(1)

(2-)methylpropan-1-ol **(1)**
Do not penalise if OH and CH_3's not fully displayed. ONLY ALLOW T.E. for name if (2-)methylpropan-2-ol is drawn. 2

[12]

32. (a) $\Delta H_{at} = (2 \times 347) + 612 + (8 \times 413) = +4610$ (kJ mol^{-1})

Method **(2)**
Answer (arithmetic and sign) **(1)**

+ 4610 *with no working* **(3)**
one multiple wrong/omitted (eg +4263/+1719) **2 max**
two multiples wrong/omitted (eg +1372) **1 max** 3

(b) (i) axes suitably labelled **with units** : "(Number of) carbon atoms" on **x-axis** and "ΔH_{at} (/) kJ mol^{-1}" on **y-axis** **(1)**

Linear and sensible scales **(1)**
ALLOW one big square per 1000 kJ. Must be one big square per carbon atom

All points correctly plotted and joined with **straight** line or dot-to-dot **(1)**
only penalise if points clearly off line

Graph of ΔH_{at} vs. Boiling point **(0)**
Graph of Boiling point vs. number of carbon atoms **(0)** 3

(ii) *1st mark: bond breaking increasing*
2nd mark: quantitative treatment

e.g.

(From one alkene to the next) involves the **atomisation/breaking of an** extra **C–C bond** and two extra **C–H bonds** **(2)**

OR

a need to break more bonds as chain length increases (1)
molecules increase by $–CH_2-$ as chain length increases (1) 2

(iii) (+) 4620 – 30 (kJ mol^{-1}) 1

(c) (i) Van der Waals *OR* fluctuating/induced dipoles *OR* London/dispersion forces
NOT vdw 1

(ii) Number of electrons increases **(1)**

so the strength of the van der Waals / **intermolecular** forces also increases
OR
so there are more van der Waals forces **(1)**
Mark independently 2

(iii) Two **geometric** isomers [*can be shown in diagram instead*]/ a cis and trans form exist
OR
Valid argument based on no free rotation about C=C bond → two isomers 1

(iv) Pent-1-ene because unbranched/straight chain **(1)**
Greater area (of contact)/more contact between molecules/molecules can align more easily **(1)**
IGNORE argument based on stacking/packing
IGNORE molecules can get closer together 2

(d) There is hydrogen bonding in water **(1)**
Alkenes cannot form hydrogen bonds (with water molecules)/alkene-water interactions too weak **(1)**
Mark independently 2

[17]

33. (a) N_2O 1

(b) Refrigerants/heat transfer agents and anaesthetics /
they share similar properties
OR properties exemplified
eg non flammable/non toxic/volatile - a*ny **two** of these*

OR

Refrigeration technology resulted in the production of CFCs which were then found to have properties of anaesthetics

OR

Refrigerants/heat transfer agents were found to be anaesthetics 1

(c) Inertness of **fluorine in the C-F bond**
Inertness of fluorine in the CF_2 / CF_3 groups
$CF/CF_2/CF_3$ group conferred stability on **adjacent/neighbouring** C—Hal bonds
NOT inertness of C-F bond/fluorine alone 1

(d) (i) There is a greater difference between the electronegativities of fluorine and hydrogen than between fluorine and chlorine / chlorine is more electronegative than hydrogen

Answer in terms of relevant relative shifts in electron densities are acceptable.
ACCEPT answers based on relative symmetries, e.g. electron cloud in CF_3CCl_3 is more symmetric than with CF_3CH_2Cl
ACCEPT argument in terms of electropositivities 1

(ii) CF_3CH_2Cl
because it possesses C–H bonds
OR enables (electrostatic) interactions with "brain molecules"
OR because a lower dose can be used 1

(e) (2) - bromo - (2) - chloro - 1,1,1 - trifluoroethane
OR
(1) - bromo - (1) - chloro - 2,2,2 - trifluoroethane
IGNORE punctuation

ACCEPT non alphabetic versions
NOT bromochlorotrifluoroethane 1

(f) 100-106.5 °
Any value or range of values within this range 1

Marking for key points
One mark should be awarded for **every** key point clearly identified in an answer.

Key points minus word penalty = maximum 6 marks

To gain the mark for a key point the wording used by the candidate must make clear the essential chemistry of the point.

Key points

<u>Advantages of using halothane</u>: Any 5 (max) of these key points

1 Halothane is non/less flammable/ non explosive/toxic.
ALLOW inverse argument with reference to $CHCl_3$, ether or 'earlier anaesthetics' **(1)**

2 It does not cause gastric irritation / post operative vomiting.
ALLOW inverse argument with reference to $CHCl_3$, ether or 'earlier anaesthetics' **(1)**

3 It is not thought to cause **irreversible** liver damage **with repeated dosage.**
ALLOW inverse argument **(1)**

4 Halothane contains a C–Br /bromine **/ C–H** bond**,** so is **safer** (to use than other CFCs).
ALLOW inverse argument **(1)**

5 Halothane produces narcosis /anaesthesia/deep sleep at low(er) doses/concentrations (than other CFCs)
OR halothane does not need high dose which lead to breathing paralysis. **(1)**

6 Halothane (was a potent inhalation agent) with a **smooth, pleasant induction** (period for the patient). **(1)**

<u>Why halothane's use declined:</u>

7 Halothane is associated with **post-operative liver dysfunction**. **(1)**

8 **Safer** and **cheaper** anaesthetics/agents (such as enflurane and isoflurane) were discovered. **(1)** 6

Quality of Written Communication

These should *be impression* marked on a scale 2-1-0, and the mark out of 2 should be recorded in the body of the script at the end of the answer. This mark can not be lost as a result of a word penalty.

Candidates are expected to:
- show clarity of expression;
- construct and present coherent argument;
- demonstrate effective use of grammar punctuation and spelling.

The aspects to be considered are:

- use of technical terms; the answer should convey a correct understanding by the writer of the technical terms used in the passage which are involved in the key points.
- articulate expression; the answer should be well–organised in clear, concise English, without ambiguity. It should read fluently, with the links between key points in the original maintained.
- legible handwriting; the reader should be able to read the answer without difficulty at normal reading pace, with only the occasional difficulty with a word.
- points must be in a logical order.

Good style and use of English, with only infrequent minor faults, no use of formulae **(2)**

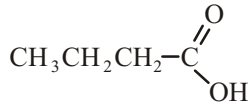
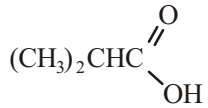
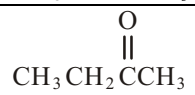
Frequent minor or a few major faults in style and use of English **(1)**

Very poor style and use of English **(0)**

NB: The quality of written communication mark cannot be lost through word penalties. 2

[7]

34. (a)

	Isomer	Complete oxidation
Primary	$CH_3CH_2CH_2CH_2OH$ **(1)** *OR* $C_2H_5CH_2CH_2OH$ *OR* $(CH_3)_2CHCH_2OH$ **(1)** *NOT* $C_3H_7CH_2OH$ etc *NOT* O**HC**$H_2CH_2CH_2CH_3$	$CH_3CH_2CH_2COOH$ **(1)** $(CH_3)_2CHCOOH$ **(1)**  **(1)** *ALLOW* $C_2H_5CH_2COOH$ *OR*  *ALLOW* $(CH_3)_2CH\ COOH$ $-CO_2H$ *allowable for COOH* C_2H_5 *allowable for* CH_3CH_2-
Secondary	$CH_3CH_2CH(OH)CH_3$ **(1)**	 **(1)** *ALLOW* $CH_3CH_2COCH_3$
Tertiary	$(CH_3)_3COH$ **(1)**	None **(1)** *MUST be stated eg* n/a *OR* no product *OR* repeat the test alcohol formula ie $(CH_3)_3COH$ *NOT just a line* ***Stand alone mark***
	Incorrect alcohol repeated ***0 (out of 2)***	

The oxidation products are stand alone marks
If three carbon alcohols shown, correct oxidation products only score 6

(b) (i) 1(-)iodopropane 1

(ii) Moist/wet/damp/aqueous/aq 1
IGNORE any reference to heat

(iii) PI_3
ALLOW PI_5
NOT names 1

(c) (i) Ethanol/propanone/aqueous ethanol/alcohol **(1)**

heat **(1)**
OR warm (under reflux)
OR boil under reflux
ALLOW 'reflux' 2
If a temperature is stated must be between 30 ° and 80 °C

(ii) $CH_3CH_2CH_2CN$
ALLOW $C_2H_5CH_2CN$
NOT C_3H_7CN 1
Cyanide group can be –C≡N but not –N≡C - if bond shown it must be correct

(iii) nucleophilic substitution 1

[13]

35. (a) Propan-2-ol
NOT prop-2-ol/ 2-propanol 1

(b) Contains >CHOH *or fully displayed*

OR carbon carrying OH/ hydroxyl/ "hydroxide" group attached to two other carbons/ two other methyl groups/ one other hydrogen
ALLOW contains CHOH/CH (OH)
NOT references to hydroxide ion/ OH^- in explanation 1

(c) $C_3H_8O + \frac{9}{2} O_2 \rightarrow 3CO_2 + 4H_2O$

OR

$2C_3H_8O + 9O_2 \rightarrow 6CO_2 + 8H_2O$

products **(1)**
balancing of equation based on correct products **(1)**

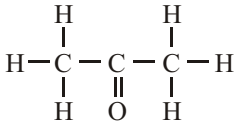
ALLOW 4.5, 4½ for $\frac{9}{2}$
IGNORE state symbols
No penalty if structural formulae used 2

(d) Bubbles/ effervescence/ fizzing **(1)**
Gets hotter/ heat produced/ temperature rises **(1)**
NOT exothermic
Sodium dissolves/ disappears/ gets smaller **(1)**
White solid produced **(1)**
Hissing sound **(1)**
any two

NOT white precipitate
NOT floats/moves around and goes on fire 2

(e) (i) Orange to green/blue 1

(ii)



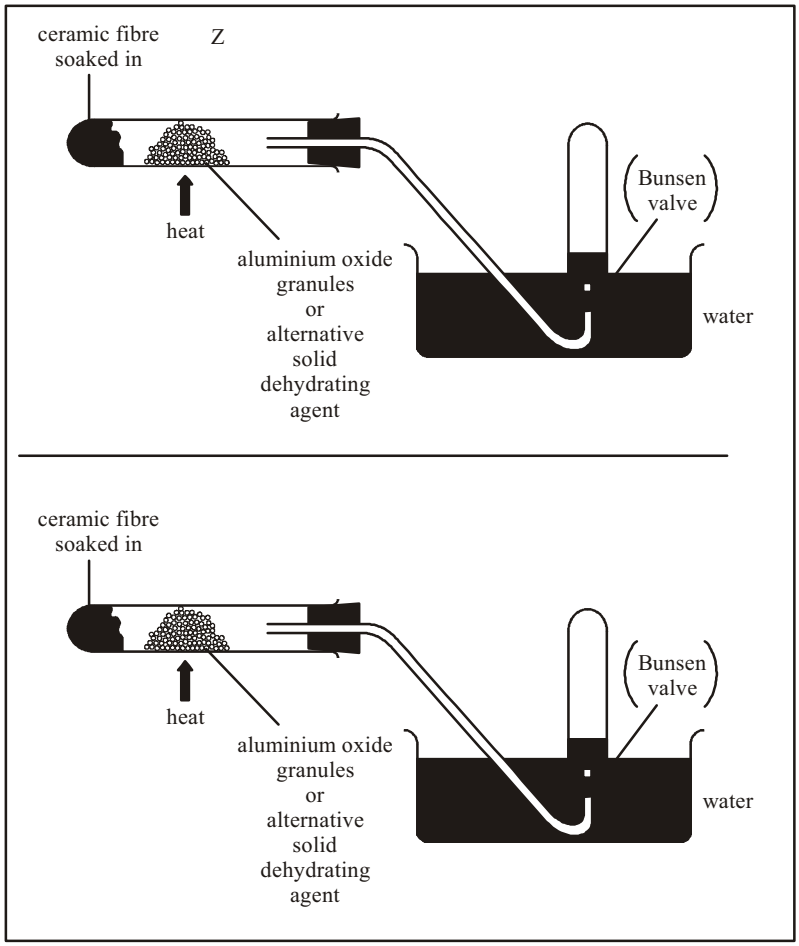
(1)
MUST be fully displayed

Propanone/ propan(e)-2-one **(1)**

ALLOW acetone
No TE from incorrect formula 2

(iii) Blue / light blue
NOT mention of any other modified colour of blue
ie *NOT* blue-green 1

(f)



3

Tube + contents **(1)**
ALLOW glass wool/ mineral wool/ Rocksil wool
NOT wire wool/ cotton wool

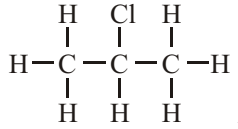
Heat under some solid **(1)**

Gas collected by displacement of water – *water does not need to be labelled*
OR collect in syringe **(1)**
IGNORE open tube following Bunsen valve, providing gas can be collected

–1 for each error
eg single line tube; gap between bung and tube; delivery tube through side of trough, delivery tube not under collecting tube

[13]

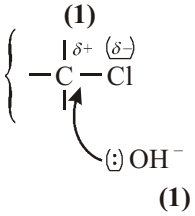
36. (a) (i) 2(-)chloropropane



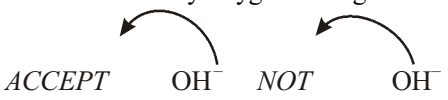
No internal TE from name to structure

MUST be fully displayed 2

(ii)

IGNORE rest of molecule 

Mark independently
Must attack the carbon
ALLOW attack by oxygen or negative charge or lone pair 2



NOT C^+

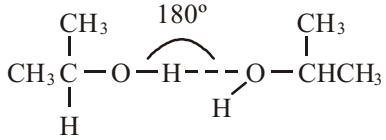
(b) (i) Elimination
NOT in conjunction with additional incorrect information
eg "nucleophile" 1

(ii) Sodium hydroxide / NaOH/potassium hydroxide / KOH **(1)**
Any additional incorrect reagent ***(0)***
NOT alkali on its own for 1st mark

Alcoholic solution / ethanolic solution **and** heat / warm / reflux **(1)**
2nd mark is dependent on mention of correct reagent or "alkali"
"aqueous" negates 2nd mark eg KOH(aq) + heat **(1)** – *ie reagent mark*
NaOH(alc) + heat **(2)** 2

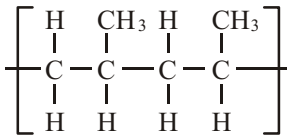
(c) (i) Hydrogen/H bonding 1

(ii)



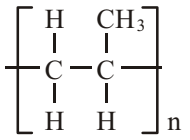
H-bond and rest of molecule ***(1)***
angle must be between 3 atoms for a correct H bond ***(1)***
ALLOW HOH 106-108° 2

(d) (i)



IGNORE any "n" in this diagram

Brackets optional but continuation must be shown
4 carbon chain with 6Cs overall in structure **(1)**
methyl groups can be on C_1 and C_3, C_1 and C_4, C_2 and C_4, C_2 and C_3 **(1)**



1 max 2

(ii) (big molecule) so large number of electrons **(1)**

Hence **large/strong van der Waals'** forces
(to be overcome to change state**)(1)** 2

[14]

37. (a) (i) (2-)methylbut(a)-1,3- diene

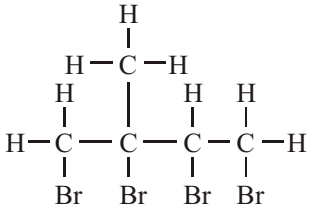
(1) **(1)**

IGNORE punctuation
ALLOW 1 max if correct answer is pre-fixed by cis / trans 2

(ii) From orange/yellow/brown to colourless **(1)**
NOT red *NOT* clear 1

(iii) addition **(1)**
electrophilic **(1)**
in either order 2

(iv)



Methyl group need not be displayed 1

(b) (i) Van der Waals' (forces)
ACCEPT Van der Walls
NOT vdw 1

(ii) Q because (unbranched) so greater area of **contact** / **closer packing**
(between molecules) **(1)**

hence greater Van der Waals/vdw forces **(1)**
2nd mark dependent on 1st
*Incorrect isomer chosen **(0)***
*Fully correct reverse argument **(2)*** 2

[9]

38. (a) (i) **How it works**
(Liquid boils and) gas/vapour **is condensed** (in condenser and runs back) **(1)**

Why it is used
Reaction slow /reaction has high activation energy /increase rate / for more time/to enable reactants to be heated for a prolonged period **(1)**

When using volatile liquids/ to prevent loss of materials / to prevent escape of reactants (and products)/ to minimise loss of reactants (and products)**(1)** 3

(ii) **Apparatus**
Flask properly drawn and thermometer and heat **(1)**

Condenser properly drawn with water jacket with correct water flow**(1)**

Set up
Top of still head closed and collection end open
Thermometer at correct point in neck (still head)
Condenser at angle **(1) ALL THREE for 1 mark**

Ignore any attempts to draw a fractionation column and a dropping funnel in a side arm. 3

(b) Use a water bath/electric heater/electric hot plate/sand bath/ oil bath
Ignore
Keep away from naked flame / use a fume cupboard 1

Reject do not use a Bunsen (unless qualified with what should be used)

[7]

39. (a) A round-bottom(ed)/distillation flask **(1)**

Accept Pear-shaped flask
Accept Flask
Accept long neck flask

Reject Liebig flask
Reject conical flask
Reject bottle ended flask
Reject volumetric flask

B (Liebig) condenser **(1)**

Accept condenser

Reject cooling water jacket
Reject condensing tube

C anti-bumping beads/granules **(1)** 3

Accept porcelain/ silica

Accept correct names in any order

(b) No stopper in top of flask **(1)**

Reject "side arm on conical flask not needed"

No jacket on condenser **(1)**

Water direction wrong way round **(1)**

Reject i.e. implying sealed apparatus

Ignore:/ neutral
"flask sealed off from rest of apparatus"
"water bath not needed"
"cork in conical flask not needed"
"gap between top of condenser & still head"
"air condenser sufficient"
"fume cupboard not needed"

Reject thermometer should be in liquid

Reject no need for anti bumping beads

If they give 4 or more errors : loses 1 mark for each "reject"
but neutral ones are ignored e.g.
3 correct + sealed apparatus = 3–1=2
3 correct+ water bath not needed = 3–0 = 3

[if this part is completely blank send to review under out of clip category] 3

(c) (concentrated) sulphuric/sulfuric acid 1

Accept dilute

(d) Oxidation **(1)** partial oxidation
hydrogen atoms lost (as organic reactant changes to product) **(1)** 2

Allow oxidation number of carbon increases (from –2 to –1)

Accept redox if the rest of the answer makes clear that the ethanol has been oxidised

Reject reduction
Reject redox

(e) (i) $Cr_2O_7^{2-}$ 1

(ii) Orange to green 1

Accept blue

(f) Ethanoic acid **(1)**
CH_3CO_2H / CH_3COOH **(1)**
Mark independently 2

Accept correct structural or displayed formula

Accept molecular formula $C_2H_4O_2$ correct if name is correct

Reject empirical formula

Reject C_2H_3OOH, CH_3CHO_2

[13]

40. (a) (i) $(18 \times 1.35) = 24.3/ 24.30$ (kJ) **(1)** 1

(ii) kJ from 1 mole = $\frac{24.3 \times 44}{0.5}$ / $\frac{24.3}{0.0114}$ / 24.3×88 **(1)**

$\Delta H = -2140$ (3SF) (kJ mol^{-1}) **(1)**
Second mark must have negative sign and 3SF
Allow TE from incorrect value in (i) 2

Accept $\Delta H = -2138.4/ -2138/+2138$ (kJ mol^{-1}) for 1 mark

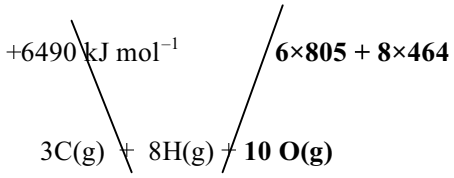
(iii) Incomplete combustion / combustion to C or CO. Not complete combustion **(1)** 1

Reject not all of the propane burns.

Reject comments on accuracy of equipment.

(b) (i)

$C_3H_8(g) + \mathbf{5}O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$



$+6490 = \Delta H_c + (6 \times 805 + 8 \times 464)$

$\Delta H_c = +6490 - 4830 - 3712$

$= -2052$ kJ mol^{-1}

Accept –2050 (kJ mol^{-1})

Balancing cycle with **5**O2 and **10 O(g)** **(1)**

$\Delta H_1 = (6 \times 805 + 8 \times 464) = (+) 8542$ (kJ mol^{-1}) **(1)**

Final value –2052 (kJ mol^{-1}) **(1)**

IGNORE SF

Allow TE from an incorrectly calculated ΔH_1 if method clear. 3

(ii) H_2O is gas in equation/ not standard state
OR mean bond energies differ from bond energies in these compounds / Environment in these compounds changes bond energies from the mean. 1

Accept H_2O is liquid in ΔH combustion calculation but ges in bond energy calculation.

Reject "mean bond energies are used" without qualification

Reject all the substances are in the gasous state

(c) (i) Free radical **(1)** substitution **(1)** 2

Accept reverse order

(ii) $2C_3H_7\bullet \rightarrow C_6H_{14}$ **(1)**

Two (propyl) radicals may combine /a radical and a molecule may produce C_6H_{14} (in a propagation step) **(1)** 2

*Accept $C_3H_7\bullet + C_3H_7\bullet \rightarrow C_6H_{14}$ **(1)***

Accept multiples

*Accept $C_3H_7\bullet + C_3H_8 \rightarrow C_6H_{14} + H\bullet$ **(1)***

Full mechanisms may be shown

(d) (i) 2-chloropropane: white precipitate/ solid /cloudiness **(1)**

Reject white colour

Reject creamy

2-iodopropane: yellow precipitate / solid **(1)** 2

*Accept ppt appears slowly with chloropropane and quickly with iodopropane **(1)***

Accept pale yellow precipitate

Accept white colour and yellow colour – 1 out of 2

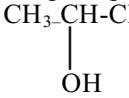
(ii) $Ag^{+}(aq) + I^{-}(aq) \rightarrow AgI\ (s)$

Formulae **(1)**
State symbols **(1)**
Minor error in formula with correct state symbols max 1 2

Accept max 1 out of 2 for wrong halide

(iii) Propan-2-ol/ $CH_3CH(OH)CH_3$ **(1)** 1

Accept displayed formula



Reject molecular formula C_3H_7OH

[17]

41. (a) (i) 2,2,4-trimethylpentane
Ignore punctuation (Commas and hyphens may be interchanged) 1

Accept 2,4,4 - trimethylpentane

Reject pentan for pentane
2-dimethyl-4
methylpentane
2,2-dimethyl-4-methyl
pentane
2-methyl-4,4-dimethyl
pentane
2,4-trimethylpentane

(ii) C_4H_9 1

Accept $C_8H_{18} \rightarrow C_4H_9$

(iii) C_2H_4 1

Reject CH_2CH_2

(iv) Positive because energy is required to break (C–C) bonds
(and not completely replaced (from new bonds made))

OR Positive because cracking requires (continuous) supply of heat so must be endothermic 1

Accept two C–C bonds are broken and one C=C made

Reject positive because it only occurs at high temperature

(v) $C_8H_{18} + 17/2\ O_2 \rightarrow 8CO + 9H_2O$

OR $2C_8H_{18} + 17\ O_2 \rightarrow 16CO + 18H_2O$

OR $C_8H_{18} + 9/2\ O_2 \rightarrow 8C + 9H_2O$ (or doubled)

Oxygen on left and correct formulae of products **(1)**
balancing **(1)**
Second mark depends on first and a sensible hydrocarbon formula must be used. 2

Accept balanced equations including CO and/or C with CO_2
17/2 can be written 8.5 or 8½
Allow balanced equations based on C_8H_{18} with a smaller alkane in the products for 1 mark eg
$C_8H_{18} + O_2 \rightarrow CO + C_7H_{16} + H_2O$ ***(1)***

(b) (i) Increase in pressure: No effect as number of moles/molecules (of gas) doesn't change during reaction **(1)**

Increase in temperature: **more NO** as forward reaction endothermic OWTTE **(1)**

One mark for two correct predictions with incorrect explanations 2

Reject increase in temperature moves equilibrium to the right

(ii) Rate increases as converter gets hotter (as reaction is exothermic) 1

(iii) N_2 / nitrogen is (major) part of air/ N_2 unreactive/ not poisonous/ not a greenhouse gas / not acidic 1

Accept correct harmful properties of other 3 gases

(iv) Line from level of reactants to maximum labelled E_A **(1)**

Curve of similar shape above existing curve, starting and finishing at same levels, with maximum above original maximum **(1)** 2

[12]

42. (a) (i) Apparatus I (heating under) reflux **(1)**

Apparatus II distillation **(1)** 2

Reject fractional distillation

(ii) (expansion of vapour will) build up pressure 1

Accept prevent explosion

Reject dangerous
OR to prevent vapour escaping

(b) (i) Reaction is vigorous
OR exothermic
OR (very) fast or violent 1

Reject dangerous

(ii) (One or both of) the **liquids** flammable
OR ethanol is flammable
OR iodoethane is flammable
OR ethanol and iodoethane are flammable 1

Reject Substances or Reactants are flammable

(iii) To allow reaction to reach completion
OR reaction is slow
OR reaction has high activation energy. 1

Accept to maximise yield

(iv) The lower range is 70 to 71
The upper range is 73 to 74
e.g.
70 to 74 °C
OR
71 to 73 °C
OR
70 to 73 °C 1

(c) In (i), (ii) and (iii) penalise 1SF on the first occasion only.
ALLOW ≥ 2SF

(i) $\frac{20.0}{254} = 0.0787$ (moles) 1

Accept 0.079 / 0.07874

(ii) 1 mol $I_2 \rightarrow$ 2 mol C_2H_5I **(1)**

Answer to (i) × 2 × 156 = 24.6 / 24.55 / 24.57 (g) **(1)**

Correct answer with some working scores **(2)**

If answer to c (i) <u>not</u> multiplied by 2 the 2nd mark only accessible if there is some attempt to work out a mole ratio or state a mole ratio in first part of calculation

N.B. $156 \times \frac{20}{127}$ will give the correct final value **(0)** 2

Accept mole ratio implied in method
OR
Mass method e.g.
127g I forms 156g C_2H_5I
20g I forms $20 \times \frac{156}{127}$
= 24.6 (g) ***(2)***

(iii) $\frac{16.7}{24.6} \times 100 = 67.9 / 67.98 / 68.0$ (%) 1

Accept CQ on (ii)

Reject yield > 100 %

[11]

43. (a) (i) 2-bromobutane
the "2" must be in front of "bromo"
Ignore punctuation and capitals 1

(ii) $CH_3CHBrCH_2CH_3 + KOH \rightarrow CH_3CHOHCH_2CH_3 + KBr$
OR
$CH_3CHBrCH_2CH_3 + OH^- \rightarrow CH_3CHOHCH_2CH_3 + Br^-$ 1

Accept C_2H_5 instead of CH_2CH_3

Allow K^+ as spectator ion

Reject eqns with NaOH

(iii) water / H_2O / aqueous ethanol 1

Accept C_2H_5OH (aq) / aqueous alcohol/KOH(aq)/aqueous
Do not penalise use of NaOH(aq) again

Reject just "ethanol / ethanolic / alcoholic (KOH)"

(iv) nucleophilic substitution (both needed) 1

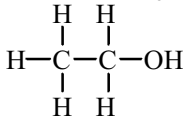
Accept reasonable phonetic spelling

(b) (i) $CH_3CHBrCH_2CH_3 + OH^- \rightarrow CH_3CH=CHCH_3 + H_2O + Br^-$
OR
$CH_3CHBrCH_2CH_3 + OH^- \rightarrow CH_2=CHCH_2CH_3 + H_2O + Br^-$
Double bond need not be shown 1

Accept C_2H_5 instead of CH_2CH_3

Ignore spectator ions

(ii) Ethanol / C_2H_5OH / CH_3CH_2OH /



1

Accept alcohol OR Ethanolic/alcoholic
Accept KOH/NaOH

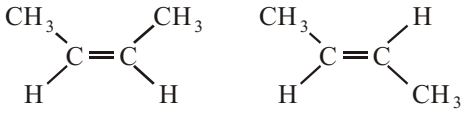
Reject C_2H_6O

Reject any mention of water/aqueous

(iii) elimination
ignore "nucleophilic" 1

Reject electrophilic elimination

(c) (i) 1



bond to H of CH_3 on left carbon
structure with 90° bond angles

(c) (ii) no / restricted rotation around double bond / C=C / π – bond (1)
has two different groups joined to **each** C (of double bond) OR each (carbon of C=C) has a CH_3 and a H (1) 2

limited rotation

on the carbon

(d) (i) nickel / Ni
OR platinum / Pt
OR palladium / Pd 1

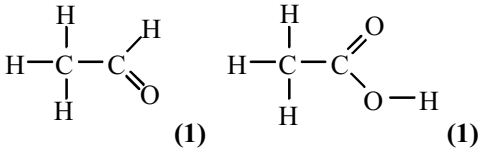
(d) (ii) butane / $CH_3CH_2CH_2CH_3$ 1

C_2H_5 for CH_3CH_2

JUST "C_4H_{10}"

[12]

44. (i)



(1) **(1)** 2

Accept –OH for –O — H

(ii) structural formula of any tertiary alcohol **(1)**
and its name **(1)** – must not contradict the formula and conditional on tertiary alcohol 2

Accept 2nd mark can be awarded if minor slip in formula or no formula given

[4]

45. (a) (i) Reaction exothermic or Reactants might evaporate 1

Accept prevent oxidation of HBr or Br^- (to bromine or Br_2)

Reject vigorous or violent or
Side reactions occur

(ii) Heated round or pear-shaped flask **(1)**
Correct vertical condenser inc. water direction **(1)**
Gas-tight joint & open apparatus **(1)** 3

↑

Accept Heat
Accept horizontal lines on flask (at joint)
Accept just arrows to indicate water direction

Reject just ↑ or just 'heat' or direct heating with a Bunsen or conical flask
Reject horizontal lines at the top of condenser

Reject distillation

(iii) Immiscible (with water) or do not mix 1

Accept immiscible with aqueous solution
Accept insoluble in water

Reject "Different densities" on its own

(iv) Drying agent or to dry product 1

Accept to remove water

Reject Dehydrate or Dehydrating agent

(v) **Either**
Use electrical heater or sand bath **(1)**
1-bromopropane is flammable **(1)**

Accept water bath
Accept flammable mixture OR propan-1-ol flammable

Reject keep away from naked flame as 1-bromopropane is flammable

Or
wear gloves **(1)**
1-bromopropane harmful by skin absorption **(1)** 2

*Accept sulphuric acid corrosive **(1)***

Reject organic liquids flammable

Reject 1-bromopropane is harmful to skin

2nd mark conditional on 1st

(b) (i) Moles propan-1-ol = $\frac{7.55}{60.0}$ **(1)**

Mass 1-bromopropane = $\left(123 \times \frac{7.55}{60.0}\right)$

= 15.5 g **(1)**

IGNORE SF 2

$7.55 \times \frac{123}{60.0}$ = 15.5 g scores full marks

Accept correct answer with some working

Reject 15.4 (from 7.5/60 or truncated)

(ii) $100 \times 8.3 \div 123 \times \frac{7.55}{60.0} = 53.6\ \%$

IGNORE SF 1

Accept $100 \times \frac{8.3}{15.5} = 53.5\%$

Accept ECF

Reject yield > 100%

(iii) Transfer losses or other products formed
or side reactions or (reaction) not complete 1

Reject experimental error or spillages
Reject evaporation (from reflux)

[12]

46. (a) (i) Iodine has more electrons/ 1-iodobutane has more electrons **(1)**
stronger/greater/larger/more Van der Waals forces **(1)** 2

Accept recognisable spellings
Accept London/dispersion/ induced dipole-induced dipole/instantaneous dipole/fluctuating dipole/flickering dipole

Reject vdw

(ii) 1-chlorobutane as less branched/unbranched **(1)**
…so molecules can align/greater surface (area of contact)**(1)**
second mark conditional on 1-chlorobutane 2

Accept …greater surface contact/many points of contact

Reject closer packing (but ignore if rest is correct)

(iii) **G** 1

(b) (i) **H** 1

(ii) **E**/1-chlorobutane **(1)**
C–Cl is strong**est**/strong**er (1)**
conditional on first mark 2

Accept it is the primary chloroalkane
Accept highest activation energy

(iii) Alcohol/hydroxy(l) 1

Accept OH

Reject OH^-/hydroxide

(iv) $Ag^+(aq) + X^-(aq) \rightarrow AgX(s)$ 1

Accept $Ag^+(aq) + Cl^-/I^-(aq) \rightarrow AgCl/I(s)$

(c) (i) High temperature/heat and pressure **(1)**
Ethanol (solvent) **(1)** 2

*Accept conc NH_3 for a period of time **(1)***

(ii) $CH_3CH_2CH_2CH_2NH_2$ **(1)**
$+ NH_4I$ **(1)** 2

*Accept $CH_3CH_2CH_2CH_2NH_3^+I^-$ **(1)***

If balancing for NH_3 gets second mark

INH_4 or $NH_4^+ + I^-$ for second mark

(iii) (1-)Butylamine / (1-)aminobutane 1

Accept butylammonium iodide

Reject butanamine

[15]

47. (a) (i) $KMnO_4$ /potassium manganate(VII) /
potassium permanganate

Accept sodium analogues

Reject just "Potassium manganate"

IGNORE any acid or alkali 1

Or
*O_2 **followed** by aqueous acid*

(ii) 1,2(-)dibromoethane 1

(iii) EITHER:
sodium bromide/NaBr /potassium bromide/KBr **(1)**

Accept HBr with concentrated/50 % sulphuric ***(1 only)***

(50 %) sulphuric acid/H_2SO_4/ phosphoric acid/H_3PO_4 **(1)**

Accept concentrated H_2SO_4

Reject dilute/aqueous sulphuric acid/ H_2SO_4

OR:
(Moist) red phosphorus/P **(1)**

Bromine/Br_2 **(1)**

Accept PBr_3 *alone* ***(1 only)***

Reject PBr_3 *plus any other reagent* ***(0)***

2nd mark is conditional on the 1st 2

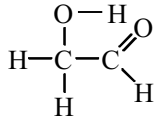
(iv) Colour change

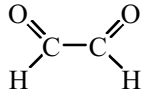
from orange to green/blue **(1)**

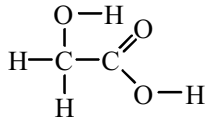
Reject …to brown

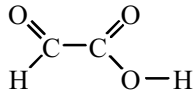
Oxidation products **(2)**

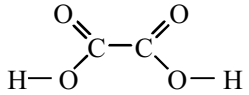
any 2 of:











Bonding from C must be to O of OH groups – penalise once only

IGNORE any names 3

Accept OH instead of O–H

*If any **two** of the following given **(1 out 2)***

Accept CH_2OHCHO

Reject CH_2OHCOH

Accept $CH_2OHCOOH$

Accept CHOCHO Or OHCCHO

Reject CHOCOH Or OHCCOH

Accept CHOCOOH Or OHCCOOH

Accept COOHCOOH Or $(COOH)_2$ Or HOOCCOOH

Allow CO_2H for COOH in the above

(v) C_2H_2/CH≡CH/ethyne

Or
CH_2=CHBr /CH_2CHBr/bromoethene 1

Accept 1-bromoethene
Accept 2-bromoethene

Reject CH_2BrCH
Reject C_2H_3Br

(b) (i) C_2H_5Br/bromoethane **(1)**

Reject side reactions

(only) monosubstitution occurs **(1)**

Reject reaction reaches equilibrium

Or
1,1-dibromoethane/CH_3CHBr_2 **(1)**

isomer of **B** / substitutes onto same carbon/Br (radical)
can remove H from either carbon **(1)**

Or
1,1,2-tribromoethane etc. **(1)**

substitution continues/ polysubstitution/reaction continues **(1)**

Or
Butane/C_4H_{10} **(1)**
Combination of two C_2H_5 radicals **(1)**

The 1st mark is stand alone in each case. 2

(ii) $C_2H_6 + 3½\ O_2 \rightarrow 2CO_2 + 3H_2O$

Accept multiples

Species **(1)**
Balancing **(1)**
IGNORE state symbols 2

Accept CH_3CH_3 instead of C_2H_6

If incorrect hydrocarbon e.g. ethene scores zero

(iii) simplest (whole number) ratio of the different **atoms**
in a compound/molecule 1

*Accept .....ratio of moles of **atoms**....*

Reject "elements" for "atoms"

(iv) CH_3 1

(v) Any alkane formula with odd no. of C atoms other than CH_4

This can be a structural, full structural or molecular formula

IGNORE names even if incorrect 1

[15]

48. (a) (i) D and F **(1)**
2,2-dimethylbutan(e)-1-ol **(1)**
conditional on the first mark

IGNORE punctuation 2

Reject but-1-ol and buta-1-ol

(ii) B / 2-methylpentan-2-ol **(1)**

carbon atom joined to hydroxyl group is attached to three other carbon atoms **(1)**

mark independently 2

Accept carbon atom joined to hydroxyl group has no hydrogens attached

Reject more than one given loses first mark

(iii) same molecular formula/same number and type of atoms **(1)**
different structural formula /different displayed formula/ different arrangement of atoms **(1)** 2

Reject same chemical formula

Reject different structure (alone)

(b) (i) D, F and C **(1)** 1

Accept D and C
or
F and C

(ii) (complete)oxidation **(1)** 1

Accept redox

Reject reduction. partial

(iii) orange to green/blue **(1)** 1

(c) (i) round-bottomed or pear-shaped flask + heat **(1)**
condenser with correct water flow **(1)**
collection vessel **(1)**

Apparatus with no joints max 2 3

Accept 2 max for non working apparatus

Accept e.g. sealed

(ii) moles of cyclohexanol =15 /100 = 0.15
AND moles of cyclohexene = 9.84/82 = 0.12 **(1)**

$$\% \text{ yield} = \frac{0.12}{0.15} \times 100 = 80\% \textbf{(1)}$$

Correct answer alone **(2)** 2

Accept moles of cyclohexanol =15/100 = 0.15 and mass of cyclohexene = 0.15 × 82 = 12.3 ***(1)***

$$\textit{\% yield} = \frac{9.84}{12.3} \times 100 = 80\% \textbf{ (1)}$$

[14]

49. (a) (i) AgI
Or AgI(s)/(ppt) 1

Accept Ag^+I^-
ie any correct answers with ***both*** *charges*

Reject Silver Iodide
Reject Ag^+I, AgI^+, AgI^-

(ii) $Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$

Accept TE of Cl, Br, X from (i)

Reject TE from AgI_3, Ag_2I *etc*

Mark independently of (i), unless acceptable answer
TE 1

Accept TE $Ag^{2+}(aq) + 2I^-(aq) \rightarrow AgI_2(s)$ *from* AgI_2 *in (i)*

Reject $Ag^+(aq) + I^-(aq) \rightarrow$ ***AgI(ppt)***

(b) (i) $C_4H_9I + H_2O \rightarrow C_4H_9OH/C_4H_{10}O + HI/IH$

IGNORE states 1

Accept "$H^+ + I^-$" for "HI"
Accept Cl, Br, or X instead of I

Allow combination of X on the left with I, Br, or Cl on the right

or X on the right with I, Br, or Cl on the left

(ii) Substitution

IGNORE nucleophilic (but note this may get 1st mark for (iii)) 1

Accept hydrolysis

Reject displacement/replacement/electrophilic/free radical substitution

(iii) Nucleophile – can be awarded from (ii) **(1)**

Because of nonbonding/unbonded /lone/unshared**pair** of **electrons** (on oxygen/water) **(1)** 2

Reject just "pair of electrons"

Reject 'spare' pair of electrons

Reject unshared pair of electrons on the hydroxide ion/OH^-

(c) (i) **ceramic fibre** in **horizontal** tube **(1)**

Accept mineral/glass/cotton wool

Reject steel wool

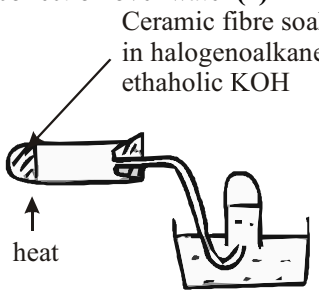
soaked in reagents /reactants/halogenoalkane and (alcoholic) KOH with heat/Bunsen **(1)**

Accept vertical flask/side arm test tube/boiling tube and reagents with heat for 2nd mark

Accept heat indicated anywhere along the test tube

Reject arrow without heat

collection over water **(1)**



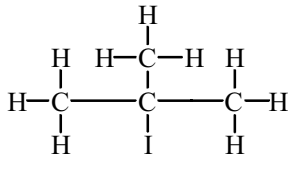
Accept syringe (with three-way tap)

IGNORE diagram and position of Bunsen valve

Penalties (cumulative)
poor diagram –1
e.g. delivery tube through side of trough/no water in trough.

Use of pumice/aluminium oxide/Al_2O_3 in test tube –1 3

(ii)



(1)

Must be fully displayed

Accept X, Cl or Br for 1st mark

Reject all other structures for 1st mark

2-iodo(-2-)methylpropane / (2-)methyl-2-iodopropane **(1)** 2

Accept chloro/bromo compounds if TE from diagram

Accept fully correct formula for 2-methyl-1-iodopropane with correct name gains 1 max again allow Br/Cl

Reject all other names for 2nd mark

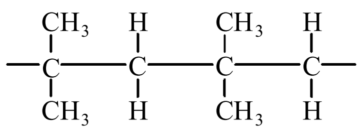
(d) Three attached methyl groups /tertiary **(1)**

*Accept two attached methyl groups /secondary **(1)***

Weaken/weaker/weak C–I/C–X/C–halogen/ C–Cl/C–Br bond
Or
Carbocation stabilised **(1)** 2

Accept the iodine /halogen/chlorine/ bromine/X bond is weak

(e) (i)



CH_3 groups on positions 1,1,3,3, <u>or</u> 2,2,4,4 <u>or</u> 1,1,4,4 <u>or</u> 2,2,3,3

Ignore brackets and n's 1

Accept part/fully displayed
Accept part/fully structural
Allow –CH_2–
Allow CH_3
|

Allow more than two units

Reject skeletal formulae (missing out hydrogens)

(ii) Reaction goes to favour lowest number of/no **gaseous/gas** molecules OR **gas** to solid 1

Reject just "by Le Chatelier's Principle"

(iii) A catalyst provides an alternative route/mechanism for a reaction… **(1)**

…with a **lower activation energy (1)**

Mark independently 2

Additional totally incorrect comment negates 2nd mark e.g. "…and provides energy for the reaction"

[17]

50. A

[1]

51. (a) A 1

(b) C 1

(c) D 1

(d) D 1

[4]

52. (a) D 1

(b) C 1

(c) A 1

[3]

53. (a) $CH_3CH_2CH_2OH$ **(1)**
Propan-1-ol **(1)**
$CH_3CH(OH)CH_3$ **(1)**
Propan-2-ol **(1)** 4

(b) (i) Propanoic acid **(1)**
$CH_3CH_2CO_2H$ **(1)** 2

(ii) Either
sodium dichromate ((VI))
or potassium manganate(VII) **(1)**

Sulfuric acid **(1)**
dependent on 1st mark
Ignore concentrated/dilute 2

[8]

54. (a) (i) Make halogenoalkanes miscible with silver nitrate/$AgNO_3$ solution
OR to dissolve halogenoalkanes/acts as solvent **(1)** 1

(ii) Feature of water molecule:
The oxygen atom has a lone pair of electrons **(1)**

Either an S_N2 mechanism
Arrow from O of water towards C atom **(1)**
and arrow from C–I σ bond to I atom **(1)**
transition state with no charge **(1)**
Ignore final loss of H^+ and formation of I^-

Or an S_N1 mechanism
Arrow from C–I σ bond to I **(1)**
intermediate with + charge and I^- ion **(1)**
arrow from O of water to C+ of intermediate **(1)**
Ignore final loss of H^+ 4

(iii) C 1

(iv) Silver((I)) chloride **(1)**
Ignore capitals 1

(v) Precipitate dissolves/disappears/clears **(1)** 1

Reject precipitate changes colour

(vi) QWC

Must be given in a logical sequence

C–I bond is weakest (and break more easily) **(1)**
Because the iodine atom is the largest / greatest bond length **(1)**
So lowest activation energy **(1)**

Or reverse argument: e.g. C–Cl bond strongest 3

Reject Cl is more electronegative than I
OR
Cl forms a carbocation more readily than C–I

(b) QWC

Any two from three:
100 % atom economy **(1)**
higher cost of halogenoalkanes/halogenoalkanes are made from alcohols **(1)**
alkenes readily available from oil **(1)** 2

(c) (i) suck back **(1)** 1

(ii) remove delivery tube from water/add Bunsen valve **(1)** 1

[15]