Mark schemes

Q1.

amount of CaS = $\frac{2.50}{72.2}$ = 0.0346 mol

M1: amount of CaS

1

amount of $CaSO_4$ = $\frac{9.85}{136.2}$ = 0.0723 mol

M2: amount of $CaSO_4$

1

3 mol of $CaSO_4$ needed for each mol of CaS, and n($CaSO_4$) is not 3 × n(CaO) (so $CaSO_4$ is the limiting reagent)

M3: limiting reagent justification

1

n(SO_2) = n($CaSO_4$) × $\frac{4}{3}$ = 0.0964 mol

M4: moles of $CaSO_4$ × 4/3

1

mass of SO_2 = n(SO_2) × 64.1 = 6.18g

M5: M4 × 64.1

If CaS used as limiting reagent then allow M4 and M5 ecf.

Must look for M1 and M3

1

[5]

Q2.

(a) M1: Mean titre = $\frac{20.25+20.30}{2}$ = 20.275 cm^3

Allow M1 = 20.28 cm^3

1

M2 Amount of NaOH = 0.35 × (20.275 ÷ 1000) = 0.00709625 mol

Amount of ethanoic acid in 25 cm^3 = 0.00709625 mol

M2 = M1 × 10^{-3} × 0.35

1

M3 Amount of ethanoic acid in 200 cm^3 = 0.05677 mol

M3 = M2 × 8

1

M4 Mass of ethanoic acid in sample = 60.0 × 0.05677 = 3.4062 g

M4 = M3 × 60.0

1

M5 Mass of sodium ethanoate = 5.6 – 3.4062 = 2.1938 g

M5 = 5.6 – M4

1

M6 percentage CH_3COONa = (2.1938 ÷ 5.6) × 100 = 39.1 %

M6 = (M5 ÷ 5.6) × 100

(39.1 – 39.2)

Accept alternative methods

M5 = (M4 ÷ 5.6) × 100) followed by M6 = 100 – M5

1

1

(b) M1 Titre value would increase / larger value

1

M2 Because the sodium hydroxide solution would be more dilute

1

[8]

Q3.

(a) ***METHOD 1***

Stage 1

M1 $n = \frac{PV}{RT}$

1

M2 converting P to 51.0 x 10^3, V to 482 x 10^{-6}

1

M3 $\frac{51.0 \times 10^3 \ \times \ 482 \times 10^{-6}}{8.31 \ \times \ 297}$ $(= 0.00996)$

1

Stage 2

M4 converting mass to 0.717

1

M5 $M_r \left(= \frac{mass}{moles}\right) = \frac{\mathbf{M4}}{\mathbf{M3}}$ = 72.0 (at least 2 sf)

1

METHOD 2

M1 $n = \frac{PV}{RT}$

M2 $M_r = \frac{mRT}{PV}$

M3 converting P to 51.0 x 10^3, V to 482 x 10^{-6}

M4 converting mass to 0.717

M5 $M_r = \left(\frac{0.717 \times 8.31 \times 297}{51.0 \times 10^{3} \times 482 \times 10^{-6}}\right)$ = 72.0 (at least 2 sf)

Both methods:

72.0 can be achieved with incorrect working and may not score because individual steps need to be assessed as correct

72.0 with no working scores no marks

*If expression not written out, **M1** could score from a substituted correct expression later on (even if any unit conversions are incorrect)*

METHOD 1

- *ECF from **M2** to **M3***
- *ECF from **M3** to **M4***
- *ECF from **M4** to **M5***
- *Ignore units for **M3***

METHOD 2

- *ECF from **M3** to **M4***
- *ECF from **M2** to **M4***
- *ECF from **M4** to **M5***

(b) **M1** amount of CO_2 formed in flask = 0.008 mol

*Allow ECF from **M1** to **M2***

1

M2 amount of gas in flask

= 0.0075 (O_2) + 0.0080 (**M1**) = 0.0155 mol

1

[7]

Q4.

C

$C_2H_4O_2$

[1]

Q5.

B

1.74×10^{-2}

[1]

Q6.

C

51.1%

[1]

Q7.

C

1.47

[1]

Q8.

B

ethanol

[1]

Q9.

(a) **M1** n = pV / RT

__M1__ for rearrangement

M2 $n = \frac{100000 \times (178/1000000)}{8.31 \times (273 + 120)}$

__M2__ for three unit conversions

M3 n = 5.45 × 10^{-3} mol

M_r = mass/mol or 0.460 / 5.45 × 10^{-3}

__M3__ for calculating the amount in moles of A

M4 M_r = <u>84.4</u> Answer must be to 3 sig.fig.

__M4__: 0.460 / __M3__ given to 3sf

4

(b) Calculated *M*r value would be greater than actual

Mr = mass / moles so dividing by too small a value of moles gives a larger Mr than expected.

1

A lower volume would have been recorded / mass evaporated less than mass of liquid / lower moles calculated / mass recorded higher than mass of gas / mass recorded would be too high

__M2__ dependent on correct __M1__

1

(c) % uncertainty = (uncertainty / mass added) x 100

= ((2 x 0.001) / 0.460} x 100 = 0.435%

1

[7]

Q10.

Percentage yield

M1 reactant moles = $\frac{1.00}{116.0}$ (= 0.00862)

*Correct **M3** scores **M1-3***
Numerical answers to at least 2sf
*Allow ECF in **M1-M3***

1

M2 product moles = $\frac{0.552}{72.0}$ (= 0.00767)

Alternative for M2/3

***M2** expected mass of product = 0.00862 x 72.0 (= 0.621 g)*

1

M3 % yield = $\frac{0.00767}{0.00862}$ = 88.9(3) or 89%

Alternative for M2/3

***M3** % yield = ($\frac{0.552}{0.621}$ x 100) = 88.9(3) or 89%*

1

M4 idea of getting as much product as possible in the reaction / idea of efficient conversion of reactants to products

1

Atom economy

M5 $\left(\frac{72.0}{74.0+34.0} x\ 100\right) = \left(\frac{72.0}{108.0} x\ 100\right) = 66.7\%$

Alternative for M5: $\left(\frac{72.0}{72.0+36.0} x\ 100\right)$

1

M6 idea of maximising the mass of reactants / atoms that ends up in desired product or idea of minimising the amount of by-products

1

[6]

Q11.

(a) **M1** n($S_2O_3^{2-}$) = 33.50 x 0.100 ÷1000 = <u>0.00335</u>

1

M2 n(I_2) = 0.00335 ÷ **2** = 0.001675 (from eqn 2)

***M2** = **M1**÷2*

1

M3 n(ClO^-) in 25 cm^3 pipette = 0.001675 (from eqn 1)

M3** = **M2

1

M4 n(ClO^-) in 100 cm^3 flask = 0.001675 **<u>x 4</u>** = 0.00670 = n(NaClO) in original 10 cm^3 sample

***M4** = **M3** x 4*

1

M5 mass (NaClO) = 0.00670 x 74.5 = 0.499 g

__M5__ = __M4__ x 74.5

1

M6 mass (bleach) = 10.0 x 1.20 = 12 g

__M6__ = mass of bleach

1

M7 % by mass of NaClO = $\frac{0.499}{12}$ = 4.16 %

__M7__ = (__M5__÷__M6__) x 100 to 3 significant figures
Allow 4.15% to 4.17%

1

(b) 0.45%

1

[8]

Q12.

C

[1]

Q13.

A

2.28×10^{-18} J

[1]

Q14.

(a) M_r NaF = 42(.0)

Incorrect M_r loses M1 & M4

1

Mass NaF in 1 g = $2.88 \times 10^{-5} \times 42.0$ (= 1.210 (1.2096) $\times 10^{-3}$ g)

1

Mass NaF in 1 kg = 1.210 (1.2096) g

M3 = M2 × 1000 (g)
Units, if given, must match answer

1

(Mass in mg = 1210 (1209.6) mg)

Concentration of NaF = 1210 (ppm)

Allow 1.21×10^3 ppm

1

(b) Toxic mass = $3.19 \times 10^{-2} \times 75 \times 1000$
= 2390 mg

Allow 2393

1

(c) Mass of toothpaste needed = $\frac{2390}{2800}$
= 0.854 kg

Mark consequential to (b)

(b) ÷ 2800 (to at least 2 sig fig)

Allow 0.85 - 0.86 kg

1

(d) B

If not B, allow M2 only

If blank, read on.

1

Both Na^+ and F^- same electron arrangement ($1s^2 2s^2 2p^6$) or isoelectronic

Electronegativity, molecules or IMF = CE, M1 only

1

Sodium (ion) has more protons so attracts (outer) electrons closer /
Sodium (ion) has more protons so stronger attractions for (outer) electrons

Ignore shielding, higher charge density, atomic radius

If reference to fluorine rather than fluoride, then penalise 1 mark only

1

[9]

Q15.

(a) **M1**: Mass Na_2CO_3 = 0.57g AND Mass H_2O = 0.55g

If incorrect masses other than AE, lose M1 & M3

1

M2: Mol Na_2CO_3 $= \frac{0.57}{106}$ AND Mol H_2O = $\frac{0.55}{18}$

M2 = process

1

M3: = 0.0054 : 0.0306

M3 = these values only (at least 2sf)

1

M4: ÷ by smallest = 1 : 5.682

M4 = process mark

1

M5: Value of × = 5.68 (2dp)

Allow 5.67 – 5.74

1

OR

M1: Mass Na_2CO_3 = 0.57g AND Mass $Na_2CO_3.xH_2O$ = 1.12g

1

M2: Moles anhydrous Na_2CO_3 = $\frac{0.57}{106}$ = 5.377×10^{-3}

1

M3: Mr of hydrated Na_2CO_3 = $1.12/5.377 \times 10^{-3}$
= 208.3

1

M4: Mr of × H_2O = 102.3

1

M5: Value of × = 5.68 (2dp)

Allow 5.67 – 5.74

1

(b) Failure to drive off all the water
OR
Failure to heat for long enough
OR
Not heated to constant mass

Allow evaporate instead of drive off

Ignore incomplete reaction

1

(c) Heat to constant mass / heat for longer / use a smaller mass

1

You can be sure all / more of the water has been driven off

Ignore incomplete reaction

M2 dependent on M1

1

[8]

Q16.

(a) The sum of $\frac{\text{(weighted) average masses of atoms in formula}}{1/12 \text{ mass of an atom of } ^{12}C}$

$\frac{\text{Average mass of one molecule}}{1/12 \text{ mass of an atom of } ^{12}C}$

1

Method 1	**Method 2**
Mass of Y = 0.21g	Mass of Y = 0.21g

If incorrect lose M5 also, unless AE

1

$M_r = \frac{mRT}{pV}$	$n = \frac{pV}{RT}$ and $M_r = \frac{m}{n}$

Can be implied in calculations

1

$M_r = \frac{0.21 \times 8.31 \times 371.1}{102000 \times 85x10^{-6}}$ n = $\frac{102000 \times 85x10^{-6}}{8.31 \times 371.1}$ (= 2.81 × 10^{-3})

M4 – awarded for all 3 unit conversions

1

M_r = 74.7 M_r = 74.7

Allow 75

1

(b) Lower volume recorded

Allow

(Evaporated) mass of gas is less than the recorded mass of liquid / 0.21g (or converse)

1

M_r would be greater (than the real M_r)

Ignore other references to mass

1

[7]

Q17.

C

[1]

Q18.

D

[1]

Q19.

(a) use of water would <u>dilute</u> the NaOH OR
use of water would change the <u>concentration</u> of NaOH OR
to ensure the <u>concentration</u> of the NaOH is not changed OR

Ignore reference to weakening the solution, watering down the solution, contaminate

Allow

it would gives a titre value that is larger

it would decrease the pH of the NaOH

(any additional qualifying reason given must be correct)

1

(b) Rough = 25.2, 1= 23.90, 2 = 23.70, 3 = 24.00.

Need all four (with rough to 1dp and the other three to 2dp)

1

(c) **M1** use of titrations 1 & 3 only

__M1__ is for choosing correct titres

1

M2 23.95 (cm^3)

__M2__ is for calculating the mean to 2dp for their chosen titres

24.0 cm^3 = 1 mark (wrong number of decimal places)

24 cm^3 = 1 mark (only if it is clear that titration 2 is not included)

23.86 cm^3 = 1 mark (used all three titrations)

23.9 cm^3 = 0 marks (used all three titrations and wrong number of decimal places)

If error(s) made in 2.2, allow ECF from 2.2, where they choose concordant titres and find the mean (can score M1 and M2)

1

(d) $(\frac{0.15}{23.95} \times 100) = 0.63\%$

(0.6263%)

Allow any correct value with at least 2 significant figures based on their answer to 2.3. Rounding must be correct.

1

(e) **M1** moles NaOH = $\frac{23.95}{1000} \times 0.0500$ (=0.001198)

1

M2 moles acid in flask = $\frac{M1}{3} \times 10$ (= 0.003992)

1

M3 mass acid (= 0.003992 x 192.0 = 0.766 g) = 766 (mg)

Correct answer to at least 2sf = 3 marks (allow 760-770 mg)

Correct value in grams (lose M3) = 2 marks (allow 0.76-0.77 g)

Allow ECF at each stage (including those based on value from 2.3)

Incorrect answers that are a factor of 10 too small lose M2 (76-77 mg = 2 marks, 0.076-0.077 g = 1 mark)

(if use 25 cm^3 for volume of NaOH, then max 2 marks (__M2__ and __M3__ for 800 mg)

1

(f) $(\frac{\text{Answer to Q (e)}}{784} \times 100) = 97.7$ or 97.8%

Allow any correct value to at least 2 significant figures based on their answer to Q(e)

(values may be over 100% if 2.5 is incorrect)

1

[9]

Q20.

M1 HCl added = <u>0.050</u> mol and
NaOH used in titration = <u>3.99×10^{-3}</u> mol

1

M2 So moles that would be needed to neutralise total excess
HCl = 3.99×10^{-3} **<u>× 10</u>** = 3.99×10^{-2} mol

Alternative: divide moles HCl by 10 = 0.005 and 0.005 - 3.99×10^{-3} = 0.00101

1

M3 Therefore the moles of HCl reacted with the $Na_2CO_3.xH_2O$ =
0.050 - 3.99×10^{-2} = 0.0101 mol

Alternative: 0.00101 × 10 to produce 0.0101

1

M4 So moles $Na_2CO_3.xH_2O$ reacted with the HCl = 0.0101 / **2** = 5.05 x 10^{-3} mol

1

M5 Conversion of mg to g = 0.627 (g) or 627×10^{-3} (g)

1

M6 xH_2O = 0.627/5.05 × 10^{-3} -106.0 = 18 (.16)

Alternative: mass Na2CO3 that reacted with the HCl 5.05 × 10^{-3} x106.0 = 0.5353 g and mass H_2O = 0.627- 0.5353 = 0.0917 g

1

M7 so *x* = **<u>1</u>**

Alternative: 0.0917 /18.0 = 5.094 × 10^{-3} so ratio Na_2CO_3 to H_2O = 1:1.009 ie 1:1 so × = 1

1

[7]

Q21.

(a) $4CuFeS_2 + 9\frac{1}{2}O_2 + 4SiO_2 \longrightarrow Cu_2S + Cu_2O + 7SO_2 + 4FeSiO_3$

Allow multiples

1

$Cu_2S + 2Cu_2O \longrightarrow 6Cu + SO_2$

1

(b) ANY TWO

- Prevents acid rain (which damages buidlings / ecology)
- Toxic OR causes breathing problems
- Reduces waste product OR makes use of the waste OR improves atom economy OR Reduces need for sulfur mining OR used to produce sulfuric acid OR any named products

2

(c) M1, M2, M3 are process marks

M1 Mol Cu = $\frac{450 \times 1000}{63.5}$ (= 63780) 1

M2 Mass $CuFeS_2$ = (63780) × 183.5 (= 1.17 × 10^7g) 1

M3 Mass ore = (1.17 × 107) × $\frac{100}{1.25}$ 1

M4 Mass ore = 936 tonnes (Allow 936 –937) 1

Alternative method
M1 % of Cu in $CuFeS_2$ = (63.5/183.5) × 100 = 34.6%
M2 % of Cu in the rock = (34.6/100) × 1.25 = 0.4325%
M3 mass of rock = 4050 × 100/0.4325 = 936416kg
M4 mass of rock in tonnes = 936 tonnes

Notes
M1 A_r Cu must be used
M2 M_r $CuFeS_2$ to have been used
M3 Grossing up for the mass of rock
M4 Final answer correct in tonnes

(d) % atom economy = $\frac{(2\times63.5)}{171}$ × 100 1

= 74.3% must be 3sf 1

[10]

Q22.

D

[1]

Q23.

B

[1]

Q24.

(a) **Stage 1**

M1 $n = \frac{PV}{RT}$ 1

M2 $= \frac{102 \times 10^3 \times 72 \times 10^{-6}}{8.31 \times 373}$ 1

M3 = 0.0024 / 0.00237 / 0.002369 / 0.0023693 .. 1

Stage 2

M4 $M_r (= \frac{\text{mass}}{\text{moles}}) = \frac{0.194}{\textbf{M3}}$ 1

M5 = 82 (**<u>2sf only</u>**) 1

*As this is an extended response question, each separate step of correct working is required in **M1–M5***

Correct answer with no working scores 2 marks

***M1** – If expression not written out, **M1** could score from a correct expression for **M2** (even if unit conversions are not correct for **M2**)*

M2** – allow an expression that gives correct value for **M3

***M3** should be <u>at least</u> 2sf (do not allow 0.0023 but do allow 0.00236)*

***M4** must show 0.194 or 194 × 10^{-3} in working to score*

***M5** must be 2sf*

ECF:

- *No ECF within either stage 1 or stage 2 (except for transcription errors)*
- *Allow ECF from stage 1 into stage 2, i.e for **M4** and **M5** based on incorrect **M3**, (but if expression for **M4** is inverted, cannot score **M5**)*
- *(Note that if 72 × 10^{-3} used in **M2**, then **M3** = 2.4, **M5** = 0.082)*

*Ignore units for **M3** and **M5***

*Note that if T = 273 + 373 = 646, **M5** = 140 (2sf)*

(b) **M1** dividing %s by relative atomic masses
C = 83.7/12(.0), H = 16.3/1(.0) 1

M2 converting (C : H 6.975 : 16.3) to 3 : 7 1

M3 empirical formula = C_3H_7 1

M4 molecular formula = C_6H_{14} 1

***M1** & **M2** are for working*

***M3** for C_3H_7 only, marked independently*

***M4** for C_6H_{14} only, marked independently (ignore additional correct structures)*

*Formulae with no working cannot score **M1** or **M2***

Alternative method:

M1 *working that shows 83.7% of 86 is 72*
M2 *idea of 72/12 gives 6 C atoms*

Alternative method:
working that shows that C_6H_{14} (or C_3H_7) contains 83.7% C scores ***M1*** *&* ***M2***

[9]

Q25.

(a) **M1** Amount NaOH = 0.02530 × 0.500 = 0.01265 mol

567-590 = 4 marks

0.567-0.590 = 3 marks

1

M2 Amount acid = 0.006325 mol (i.e. **M1** ÷ 2)

Allow ECF at each stage

1

M3 M_r = 90(.0)

M3 *can be scored from use of value of 90(.0) within working*

1

M4 mass acid = 569 (mg) (allow 567 to 576) (i.e. **M2** × **M3** in mg)

M4 *should be to at least 2sf. Any individual marks for* ***M1/2/3*** *should be to at least 2sf (or 90 for* ***M3****)*

1

1134-1180 = 3 marks (due to not dividing moles of NaOH by 2)

1.134-1.180 = 2 marks (due to not dividing moles of NaOH by 2 and not converting to mg)

(b) Idea that it ensures all ethanedioic acid / acid / sodium hydroxide / alkali / reactants are in the mixture / solution / reaction or the idea that some of the ethanedioic acid / acid / sodium hydroxide / alkali / reactants would be on the sides of the flask

the idea that it is the transfer of all the acid/alkali alone is not enough

1

(c) Titres that are within 0.1 cm^3 of each other

Units are needed

Allow 0.05-0.15 cm^3

Do not allow idea of identical results

Allow answers that refer to titres that are within the uncertainty of the burette/apparatus of each other

1

[6]

Q26.

(a) Mass of **X** = 0.270

Volume of **X** = 105.0

Both must be correct

1

(b) pV = nRT

$$\frac{100\,000 \times 105/1000000}{8.31 \times 370} = n$$

1

n = 3.41 × 10^{-3}

1

M_r = $^{mass}/_{mol}$ or $^{0.270}/_{3.41 \times 10^{-3}}$

1

M_r = 79.1

1

Identity of **X** = CH_2Cl_2

If M_r = 52 used, allow CH_3Cl

1

(c) **M1** The volume of the gas in the syringe (V) is greater than the true volume (because some air leaked into the syringe)

If the M_r value of 52 is used and CH_3Cl is identified in 01.2:

1

M2 M_r = m/n = m × RT/PV so if V is too large, M_r is too small

OR

M1 The temperature measured (T) is less than the temperature of the gas in the syringe (because the syringe heated faster than the oven and the oven temperature was not constant)

M2 M_r = m/n = m × RT/PV so if T is too small, M_r is too small

OR

M1 The measured mass of liquid transferred to the syringe (m) is less than the actual mass transferred

M2 M_r = m/n = m × RT/PV so if m is too small, M_r is too small

***M1** The volume of the gas in the syringe (V) is less than the true volume (because not all the liquid vaporised in the syringe)*

***M2** M_r = m/n = m × RT/PV so if V is too small, M_r is too large*

OR

***M1** The temperature measured (T) is greater than the temperature of the gas in the syringe (because the syringe heated more slowly than the* *thermometer and the oven temperature was not constant)*

M2 *M_r = m/n = m × RT/PV so if T is too large, M_r is too large*

OR

M1 *The measured mass of liquid transferred to the syringe (m) is greater than the actual mass transferred*

M2 *M_r = m/n = m × RT/PV so if m is too large, M_r is too large*

1

(d) Carry out in a fume cupboard

Do not allow safety glasses / labcoat

1

To avoid toxic vapour

1

[10]

Q27.

D

[1]