M1. (a) **M1** $MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$ **1**

OR multiples

M2 An oxidising agent is an electron acceptor OR receives / accepts / gains electrons

Ignore state symbols

M2 NOT an "electron pair acceptor" **1**

M3 MnO_2 is the oxidising agent

Ignore "takes electrons" or "takes away electrons" **1**

(b) **M1** Formation of SO_2 and Br_2 (could be in an equation) **1**

M2 Balanced equation

Several possible equations

$\mathbf{2}KBr + \mathbf{3}H_2SO_4 \rightarrow \mathbf{2}KHSO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$

OR

$\mathbf{2}KBr + 2H_2SO_4 \rightarrow K_2SO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$ **1**

M3 $\mathbf{2}KBr + Cl_2 \rightarrow \mathbf{2}KCl + Br_2$

M2 Could be ionic equation with or without K^+

$\mathbf{2}Br^- + \mathbf{6}H^+ + \mathbf{3}SO_4^{2-} \rightarrow Br_2 + \mathbf{2}HSO_4^- + SO_2 + \mathbf{2}H_2O$

$(\mathbf{3}H_2SO_4)$

$\mathbf{2}Br^- + \mathbf{4}H^+ + SO_4^{2-} \rightarrow Br_2 + SO_2 + \mathbf{2}H_2O$

$(\mathbf{2}HBr + H_2SO_4)$

Accept HBr and H_2SO_4 in these equations as shown or mixed variants that balance.

Ignore equations for KBr reacting to produce HBr

M3 Could be ionic equation with or without K^+

$\mathbf{2}Br^- + Cl_2 \rightarrow \mathbf{2}Cl^- + Br_2$ **1**

M4 % atom economy of bromine

$$= \frac{Br_2}{2KBr + Cl_2} \times 100 = \frac{(2 \times 79.9)}{238 + 71} \times 100 = \frac{159.8}{309} \times 100$$

= **51.7%** OR **52%**

M4 Ignore greater number of significant figures **1**

M5 One from:

- High atom economy
- Less waste products
- Cl_2 is available on a large-scale
- No SO_2 produced
- Does not use concentrated H_2SO_4
- (Aqueous) KBr or bromide (ion) in seawater.
- Process 3 is simple(st) or easiest to carry out

M5 Ignore reference to cost
Ignore reference to yield

1

(c) **M1** HBr **–1**

1

M2 HBrO **(+)1**

1

M3 Equilibrium will shift to the right
OR
L to R
OR
Favours forward reaction
OR
Produces more HBrO

1

M4 **Consequential on correct M3**
OR
to oppose the loss of HBrO
OR
replaces (or implied) the HBrO (that has been used up)

1

[12]

M2. (a) Electronegativity increases

1

Proton number increases (increase in nuclear charge)

1

Same number of electron shells/levels

Or same radius or Shielding of outer electrons remains the same

1

Attraction of bond pair to nucleus increases

Allow 'electrons in bond' instead of 'bond pair'

1

(b) Big difference in electronegativity leads to ionic bonding, smaller covalent

Lose a mark if formula incorrect

1

Sodium oxide ionic lattice

1

Strong forces of attraction between ions

1

P_4O_{10} covalent molecular

Must have covalent and molecular (or molecules)

1

Weak (intermolecular) forces between molecules

Or weak vdW, or weak dipole–dipole between molecules

1

melting point Na_2O greater than for P_4O_{10}

Or argument relating mpt to strength of forces

1

(c) Moles NaOH = 0.0212 × 0.5 = 0.0106

M1 moles of NaOH correct

1

Moles of H_3PO_4 = 1/3 moles of NaOH (= 0.00353)

M2 is for 1/3

1

Moles of P in 25000 l = $0.00353 \times 10^6 = 3.53 \times 10^3$

M3 is for factor of 1,000,000

1

Moles of P_4O_{10} = $3.53 \times 10^3/4$

M4 is for factor of 1/4 (or 1/2 if P_2O_5)

1

Mass of P_4O_{10} = $3.53 \times 10^3/4 \times 284 = 0.251 \times 10^6$ g

= 251 kg

(Or if P_2O_5 3.53 × 10^3/2 × 142)
M5 is for multiplying moles by M_r with correct units
allow conseq on incorrect M4
(allow 250-252)

1

[15]

M3.(a) percentage of oxygen is 58.33

1

correct calculation of ratios (C 3.125, H 4.17, O 3.645)

1

clearly relates ratios to formula eg
simplifies ratios (C 1, H 1.29, O 1.17) or for H then 3.125 × 8 / 6 = 4.17% etc

1

Notes
* *correct percentage of oxygen can be stated or shown clearly in a calculation*
* *to score final mark must **clearly** show how ratios relate to $C_6H_8O_7$*
* *allow full credit to candidate who correctly finds*
  percentage of oxygen
  calculates M_r
  shows percentage of H is 8 divided by M_r

(b) carbon dioxide / CO_2

1

(c) (i) suitable reaction vessel
eg sealed flask or test-tube with side arm or
eg tube in bung

1

suitable collection method
eg gas syringe / over water in measuring
eg cylinder

1

Notes
* *collection vessel must allow measurement of gas*
* *if apparatus would leak lose second mark*
* *ignore heating*

* *can draw tubing as single line*
* *accept 2D or 3D diagrams*
* *do not need labels, and ignore mis-labelling*

(ii) (1) mass on *x*-axis

1

Notes
* *If axes unlabelled use data to decide that mass is on the x-axis*

sensible scales

1

Notes
* *lose this mark if the* ***plotted points*** *do not cover at least half of the paper*
* *lose this mark if the graph plot goes off the squared paper*

plots points correctly ± one square

1

(2) draws appropriate straight line of best fit, omitting point at 1.17g / 86 cm^3

Notes
* *lose this mark if the line deviates towards the point at 1.17g / 86 cm^3*
* *candidates does not have to extrapolate the line to the origin to score this mark*
* *when checking for best fit, candidate's line* ***must*** *go through the origin ± one square. Extend candidate's line if necessary*

1

(3) 129 ± 1 cm^3

Notes
* *accept this answer* ***only***

1

(d) CO_2 / gas formed distends stomach / produces wind / increases pressure in stomach

1

(e) molecular formula has to be a simple multiple of the empirical formula

1

so approximate M_r value will distinguish between the options or equivalent wording

1

(f) gas escapes before bung inserted any 2 × 1 for

syringe sticks

carbon dioxide soluble in water

Notes
* *do **not** accept 'operator error' / 'inaccurate equipment' / 'equipment leaks'*

2

(g) volume depends on pressure and temperature

Notes
* *do **not** accept 'to get a more accurate result' or equivalent wording without qualification*

1

(h) Tablets could vary between samples or equivalent wording

Notes
* *do **not** accept 'to get a more accurate / reliable result' or 'to make a fair test' without qualification*

1

(i) (i) $NaHCO_3$ **least** soluble

1

(ii) exhaust gases passed into mixture of NaCl and NH_3

1

(j) $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

Notes
* *accept multiples*

1

(k) 106.0 divided by 217.1 × 100 = 48.8%

Notes
* *ignore precision of answer*

1

[22]