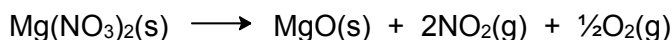


OR



- (b) Correctly stated volume, with units, of apparatus to be used for gas collection.
E.g. 100 ml or 100 cm³ gas syringe [1]

AND

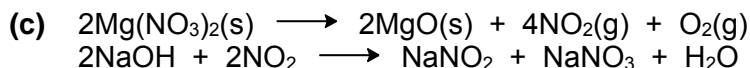
Correctly calculated mass of magnesium nitrate to produce a stated volume of O₂ gas that would be appropriate for the stated volume of apparatus.

E.g. for 60 cm³ of O₂,

$$n(\text{O}_2) = 60/24000 = 2.50 \times 10^{-3} \text{ mol}$$

$$n[\text{Mg}(\text{NO}_3)_2] = 2 \times n(\text{O}_2) = 5.00 \times 10^{-3} \text{ mol}$$

$$\text{mass of Mg}(\text{NO}_3)_2 = 5.00 \times 10^{-3} \times [24.3 + 2(14.0) + 6(16.0)] = \underline{0.742 \text{ g}} \quad [1]$$



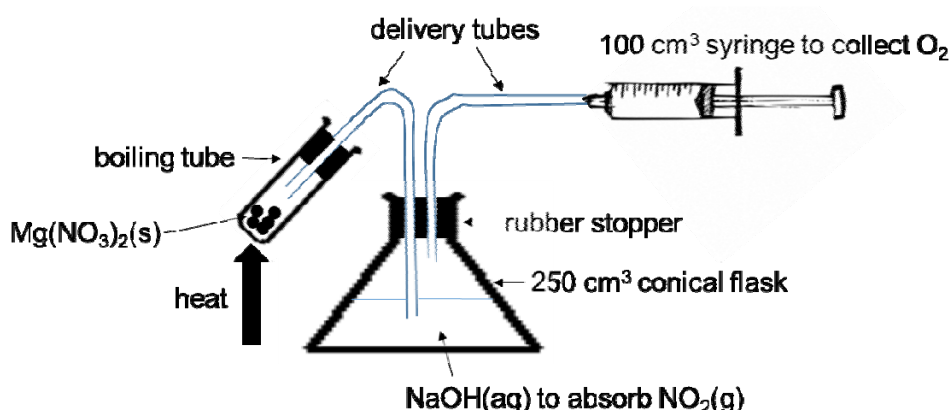
$$n(\text{NO}_2) = 2 \times n[\text{Mg}(\text{NO}_3)_2] = 2 \times 5.00 \times 10^{-3} = 0.0100 \text{ mol}$$

$$n(\text{NaOH}) = n(\text{NO}_2) = 0.0100 \text{ mol}$$

$$\text{min. volume of } 1.00 \text{ mol dm}^{-3} \text{ NaOH needed} = 0.0100 / 1.00 \times 1000 = \underline{10.00 \text{ cm}^3} \quad [1]$$

- (d) A diagram of the assembled apparatus capable of absorbing the nitrogen(IV) oxide and collecting the oxygen separately and in sequence [2]

- Directly heated vessel (boiling tube) labelled magnesium nitrate with tube at exit
- Gas stream led into a liquid labelled (1.00 mol dm⁻³) NaOH which will absorb the nitrogen(IV) oxide / NO₂
- Collects a gas in a syringe or over a liquid, provided it is properly connected
- All parts of the apparatus are connected and air-tight AND nitrogen(IV) oxide absorption precedes oxygen collection



An outline of how the results would be obtained and measures to ensure reliability of results

[4]

1. Record the mass of the empty boiling tube.
2. Weigh accurately about 0.75 g of magnesium nitrate into a boiling tube.
3. Using a burette, add 20.00 cm³ of 1.00 mol dm⁻³ sodium hydroxide into the chamber collecting nitrogen(IV) oxide / NO₂.
4. Set up the apparatus according to the diagram above.
5. After ensuring that all the connections are properly sealed, start heating the magnesium nitrate in the boiling tube. Heat strongly for about 5 minutes, moving the boiling tube to ensure even heating of the solid. Continue heating until no further bubbling is seen in the sodium hydroxide solution and the syringe shows no further change in volume of oxygen gas collected.
6. Remove the delivery tube from the alkali before taking the boiling tube off the flame. *(To prevent back flow of liquid into the boiling tube due to cooling of air)*
7. Allow all the apparatus and chemicals to cool to room temperature before taking measurements.
8. Weigh the boiling tube and residue. Subtract the mass of the empty boiling tube to determine the mass of magnesium oxide produced.
9. Transfer all the sodium hydroxide solution into a 100 cm³ volumetric flask. Top up to the mark with distilled water. Stopper the flask and shake well to obtain a homogeneous solution.
10. Pipette 25.0 cm³ of the solution into a 250 cm³ conical flask for titration.
11. Add a few drops of methyl orange indicator. Titrate with the 0.20 mol dm⁻³ hydrochloric acid from the 50.00 cm³ burette until the solution turns from yellow to orange.
12. Repeat the titration until consistent results within ± 0.10 cm³ are obtained.
13. Record the volume of oxygen gas collected in the syringe.

Brief, but specific, details of how results will be used to determine the amounts in moles of reactant and all products at the end of complete thermal decomposition AND confirm that the decomposition had occurred according to the molar ratios in the equation

$$n(\text{MgO}) = \text{mass of MgO} / M_r \text{ of MgO} = x \text{ mol}$$

$$\begin{aligned} n(\text{NO}_2) &= n(\text{NaOH that reacted with NO}_2) \\ &= (20/1000 \times 1) - [(\text{vol. of HCl}/1000 \times 0.20) \times 100/25.0] = y \text{ mol} \end{aligned}$$

$$n(\text{O}_2) = \text{volume of O}_2/24000 = z \text{ mol}$$

}

[1]

Compare each of the values x , y and z with $n[\text{Mg}(\text{NO}_3)_2]$ used ($\approx 5.00 \times 10^{-3}$ mol) to check if the decomposition has occurred according to the molar ratios in the equation.

[1]

[Total: 12]

- 2 (a) (i) B atom in BF_3 molecule is electron-deficient as it has only 6 electrons around it. [2]
Hence, the B atom can accept another 2 electrons from the lone pair of O atom in ethoxyethane molecule. By forming a dative bond with the O atom of $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$, the B atom achieves the octet configuration.



(b) (i)
$$K_{\text{partition}} = \frac{\text{concentration of J in ethoxyethane (organic layer)}}{\text{concentration of J in water (aqueous layer)}}$$

$$= \frac{2.14 / 20}{(5 - 2.14) / 75} = \underline{2.81}$$
 [1]

- (ii) 1st extraction [2]

$$2.81 = (x / 10) / [(5 - x) / 75]$$

$$2.81 (5 - x) = 7.5 x$$

$$x = 1.36 \text{ g}$$

2nd extraction

Mass of **J** remaining in aqueous layer after 1st extraction = $5.00 - 1.36 = 3.64 \text{ g}$

$$2.81 = (y / 10) / [(3.64 - y) / 75]$$

$$2.81 (3.64 - y) = 7.5 y$$

$$y = 0.992 \text{ g}$$

$$\therefore \text{total mass of J extracted} = 1.36 + 0.992 = \underline{2.35 \text{ g}}$$

- (iii) It is more efficient to use two successive portions of 10 cm^3 ethoxyethane than one 20 cm^3 portion of ethoxyethane since total mass of **J** extracted is greater using two successive portions. [1]

- (c) Anhydrous calcium chloride (drying agent) was added to remove water present in the organic layer. [1]

[Total: 8]

- 3 (a) Giant covalent structure with strong covalent bonds between P atoms. [1]

Relatively high melting point **OR** insolubility in organic solvent (methylbenzene) [1]
suggests strong bonding throughout the structure.

- (b) type of hybridisation: sp [1]



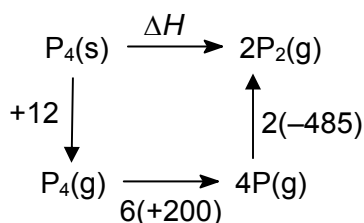
[1]

- (c) (i) Phosphorus-phosphorus triple bonds are much weaker than nitrogen-nitrogen triple bonds as phosphorus atoms are too big to come close enough together to form strong bonds. [1]

OR

Orbitals of P are larger and more diffused hence overlap of orbitals is less effective.

- (ii) [2]



$$\begin{aligned}
 \Delta H &= +12 + 6(+200) + 2(-485) \\
 &= \underline{+242 \text{ kJ mol}^{-1}}
 \end{aligned}$$

[1]

- (iii) Increase temperature [1]

$$\Delta G = \Delta H - T\Delta S$$

Since $\Delta H > 0$, $\Delta S > 0$ (as there is an increase in no. of moles of gas),
for ΔG to be negative (i.e. spontaneous), magnitude of $T\Delta S$ must be greater than that of ΔH . Hence, T must be large. [1]

- (d) (i) High temperature (needed for reaction between N_2 and O_2) [1]

- (ii) $2\text{NO} + 2\text{CO} \longrightarrow \text{N}_2 + 2\text{CO}_2$ [1]
OR $2\text{NO} + \text{C} \longrightarrow \text{N}_2 + \text{CO}_2$

[Total: 12]

- 4 (a) (i) A ligand is a neutral molecule or an anion which possesses at least one lone pair of electrons which can be used to form dative bonds with the central atom or ion. [1]

(ii) *Transition element complexes are often coloured:*

In the presence of ligands, the d orbitals of transition metal ion are split into two levels.

The energy gap E between the non-degenerate orbitals is small and corresponds to that in the visible light region. [1]

Energy is absorbed from the visible region when an electron is promoted from a lower level d orbital to a vacant higher level d orbital (d-d transition). [1]

The colour of the transition metal complex is the complement of the colour absorbed. [1]

The colour of a complex of a given transition element often changes when the ligands around it are changed:

The size / magnitude of the energy gap E depends on the ligand. [1]

(Since $E = hc / \lambda$),

When the ligand changes, E changes, λ (absorbed) also changes (hence colour of the complex changes). [1]

- (b) (i) Let O.N. of C in $C_2O_4^{2-}$ be x

$$2(x) + 4(-2) = -2$$

$$x = \underline{+3}$$

[1]

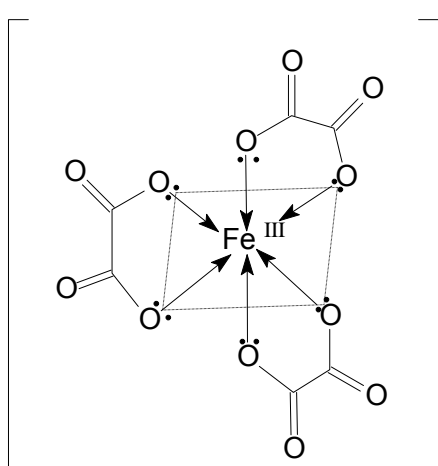
- (ii) Let O.N. of Fe in $[Fe(C_2O_4)_3]^{3-}$ be y

$$y + 3(-2) = -3$$

$$y = \underline{+3}$$

[1]

- (iii) [3- [2]

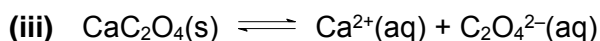


- (c) (i) $K_{sp} = [Ca^{2+}][C_2O_4^{2-}]$

[1]

- (ii) $[C_2O_4^{2-}] = (2.3 \times 10^{-9})^{1/2} = \underline{4.80 \times 10^{-5} \text{ mol dm}^{-3}}$

[1]



Increase in $[\text{Ca}^{2+}]$ due to the presence of the common ion Ca^{2+} (from CaCl_2) in solution **W** shifts the position of the above equilibrium to the left. Hence, $[\text{C}_2\text{O}_4^{2-}]$ in solution **W** is less than that calculated in **(c)(i)**. [1]

(d)

cation	ionic radius / nm
Na^+	0.095
Mg^{2+}	0.065
Al^{3+}	0.050

[1]

The charge density of the cation increases from Na^+ to Mg^{2+} to Al^{3+} . Thus, the polarising power of the cation increases in the same order.

As a result, NaCl does not hydrolyse in water ($\text{pH} = 7$); MgCl_2 hydrolyses only to a small extent ($\text{pH} = 6.5$) and AlCl_3 hydrolyses to a larger extent ($\text{pH} = 3.0$). [1]

[Total: 15]

- 5 (a) The actual value for the enthalpy of hydrogenation of benzene is less exothermic as more energy is needed to break the bonds in benzene due to delocalisation of the π electrons. [1]

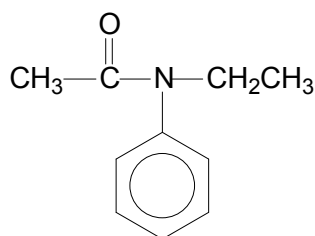
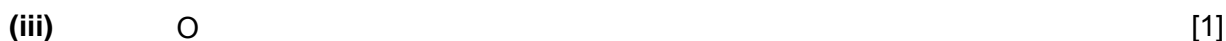
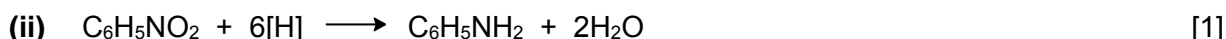
OR

Benzene is resonance-stabilised and hence has a lower energy level.

- (b) reagents: conc. HNO_3 + conc. H_2SO_4 } [1]
 conditions: $55 - 60^\circ\text{C}$
 electrophile: NO_2^+ [1]

- (c) (i) In phenylamine, the lone pair on the N atom is delocalised into the benzene ring, making the ring more electron-rich. [1]

Hence, the ring is more susceptible to (electrophilic) attack and hence does not require the strong electrophile Br^+ generated by the reaction between Br_2 and FeBr_3 . [1]



X

(d) 3 : 14 : 9

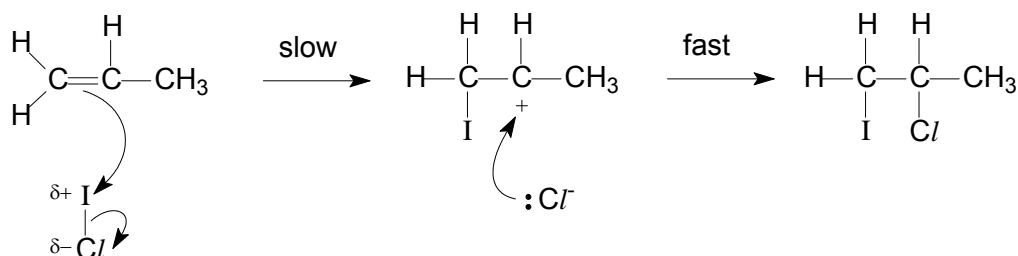
[1]

Relative rate suggests 1 : 7 : 1, but there are 3 primary to 2 secondary to 9 primary hydrogen atoms in L, M and N respectively.

[1]

[Total: 9]

6 (a) (i) [3]



(ii) ICl is polar while pure halogens are not.

[1]

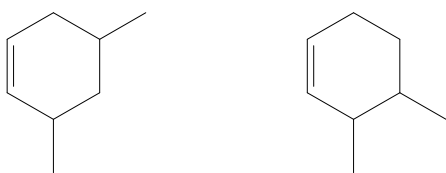
(b) number of σ bonds: 14
number of π bonds: 2 }

[1]

(c) (i) ethene

[1]

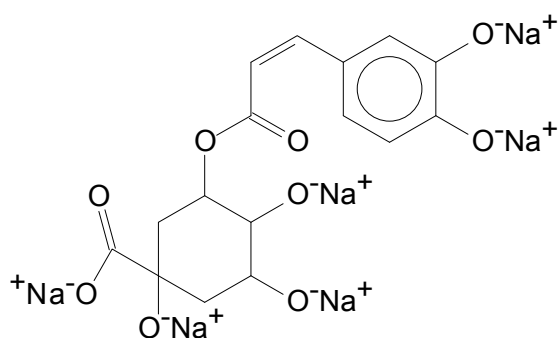
(ii)



[2]

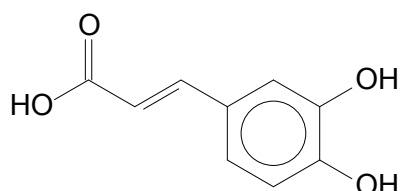
(d) (i)

[1]



(ii) (acid) hydrolysis

[1]



[1]

C

(iii) alkene **OR** $\text{C}=\text{C}$

[1]

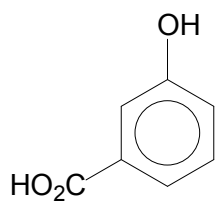
(iv) $\text{Na}_2\text{CO}_3(\text{aq})$: carboxylic acid
 $\text{Br}_2(\text{aq})$: phenol

[1]

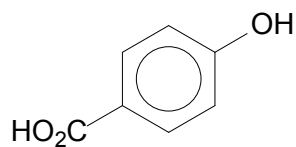
[1]

(v)

D:

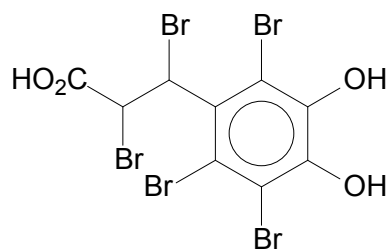


OR



[1]

E:



[1]

[Total: 16]