1 Oxygen reacts with many elements.

(a) (i) State the total number of electrons that occupy the 2p sub-shell in an oxygen atom.

.....

.....

[1]

(ii) Name the orbital that contains the highest energy electron in an oxygen atom. Draw the shape of this orbital.

name .....

shape

[1]

(b) Lithium reacts with oxygen to produce lithium oxide, Li_2O.

Li_2O is a white solid with a melting point over 1400 °C.

Draw a dot-and-cross diagram to show the arrangement of **all** the electrons in Li_2O.

[2]

(c) Li_2O reacts with water to produce a solution with pH greater than 10.

(i) State the name of a Period 3 oxide that behaves in the same way as Li_2O when added to water.

.....

[1]

(ii) Construct an equation for the reaction of Li_2O with water.

.....

[1]

(iii) Identify **all** the Period 3 chlorides that are solid at room temperature and that react with water to produce an acidic solution.

.....

.....

[2]

(d) $LiNO_3$ decomposes on heating to produce Li_2O, O_2 and a brown gas.

Identify the brown gas.

.....

[1]

(e) Ammonia is made in the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92.4\,kJ\,mol^{-1}$$

A temperature of 400–450 °C is used in the Haber process.

(i) State **two** other conditions used in the Haber process.

1 .....

2 .....

[2]

(ii) Describe how the initial rate of the forward reaction changes, if at all, when a temperature greater than 450 °C is used. Explain your answer.

Assume all other variables remain constant.

change in initial rate .....

explanation .....

.....

.....

[3]

[Total: 14]

2 (a) Protons, neutrons and electrons are released with the same velocity from a source. Figure 2.1 shows the movement of two of these types of particle when they travel between oppositely charged plates.

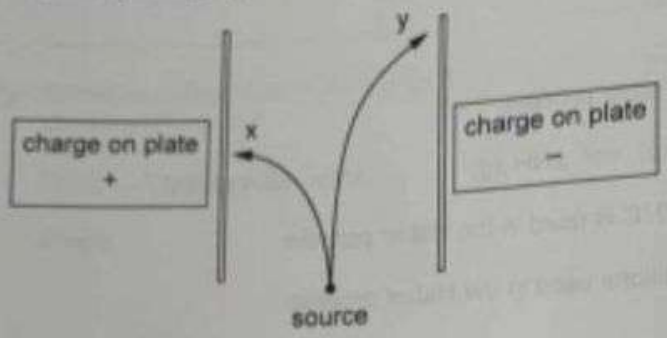


Figure 2.1

(i) Name each type of particle that produces the deflection shown by curves x and y.

curve x = ...

curve y = ...

[1]

(ii) Suggest why the particles producing curve y are deflected less than the particles producing curve x.

.....

..... [1]

(b) A student considers the information in Table 2.1 and proposes hypothesis 1.

hypothesis 1 'Atoms with a higher nuclear charge are always larger.'

Table 2.1

atom	atomic number	mass number	atomic radius / nm
A	6	12	0.077
B	17	37	0.099
C	14	28	0.117

(i) Identify a pair of atoms from Table 2.1 that supports hypothesis 1.

.....

[1]

(ii) Identify a pair of atoms from Table 2.1 that shows hypothesis 1 is false.

.....

[1]

(iii) Explain why atom **A** is smaller than atom **C**.

.....

.....

.....

.....

[2]

[Total: 6]

3 Separate samples of NaCl and NaBr are reacted with concentrated H_2SO_4.
Table 3.1 shows the observations for each reaction.

Table 3.1

reaction	compound	observations
1	NaCl	• effervescence • steamy fumes that turn blue litmus paper red
2	NaBr	• effervescence • steamy fumes initially that turn blue litmus paper red • brown vapour • pungent smelling gas

(a) (i) Write an equation for reaction 1.

.....

[1]

(ii) Explain why reaction 1 is described as a Brønsted–Lowry acid–base reaction.

.....

.....

.....

[2]

(b) Identify the formula of each species responsible for the observations in reaction 2.

steamy fumes .....

brown vapour .....

pungent smelling gas .....

[3]

(c) Explain why reaction 2 produces brown vapour.

.....

.....

[1]

(d) Explain why a gas with a pungent smell is **not** produced in reaction 1 but is produced in reaction 2.

.....

.....

[1]

[Total: 8]

4 (a) Figure 4.1 shows two reactions of compound **D**.

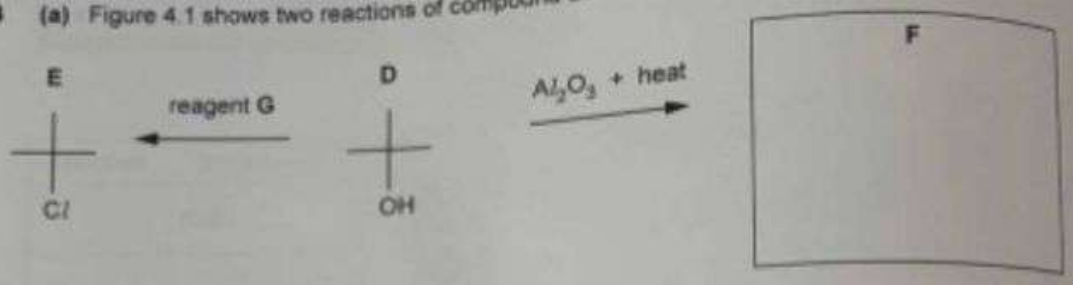


Figure 4.1

(i) **D** reacts with a single reagent, **G**, to produce compound **E**. Identify reagent **G**.

.....[1]

(ii) **D** is heated with Al_2O_3 to produce organic compound **F**.
Identify the role of Al_2O_3 in this reaction.

.....[1]

(iii) Draw the structure of **F** in Figure 4.1. [1]

(b) The structure of compound **X** is shown in Figure 4.2.

X

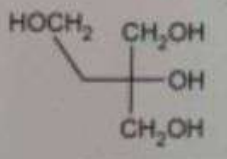


Figure 4.2

The molecular formula of **X** is $C_5H_{12}O_4$. Complete oxidation of 0.255 g of **X** occurs when it reacts with exactly 10.0 cm^3 of 0.500 mol dm^{-3} acidified $K_2Cr_2O_7$(aq).

(i) Describe the colour change in this reaction.

colour of mixture at start of the reaction .....

colour of mixture after the reaction .....

[1]

(ii) Calculate the amount, in mol, of $K_2Cr_2O_7$(aq) used in the reaction.

amount = ... mol [1]

(iii) Calculate the amount, in mol, of **X** present in the 0.255 g sample.

amount = ... mol [1]

(c) (i) Compounds **X** and **W** are a pair of structural isomers.

0.0012 mol of **W** is completely oxidised when it is heated under reflux with exactly 0.0020 mol of acidified $K_2Cr_2O_y$(aq) to produce compound **Z**.

Complete the equation for this reaction.

W **Z**

$3C_5H_{12}O_4$ + ...$Cr_2O_7^{2-}$ + ...H^+ → $3C_5H_6O_5$ + ...Cr^{3+} + ...H_2O

[2]

(ii) Each molecule of **W** contains four hydroxyl groups. Only two of these are primary hydroxyl groups.

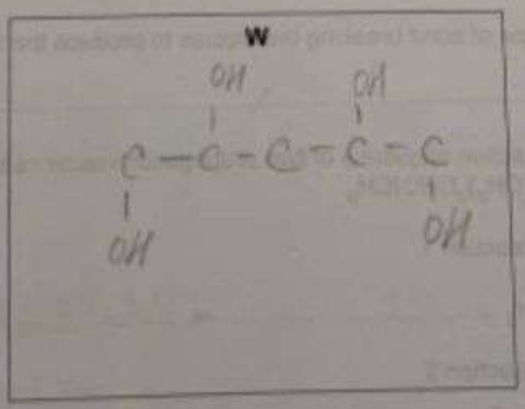
Table 4.1 shows the observations when separate samples of **Z** are added to each reagent.

Table 4.1

reagent	observations with Z
2,4-dinitrophenylhydrazine (2,4-DNPH)	orange precipitate
Fehling's reagent	none

Use the information in **4(c)** to suggest the structure of **W**.

W



[2]

[Total: 10]

5 Hexane, $CH_3(CH_2)_4CH_3$, reacts with $Cl_2(g)$ in the presence of ultraviolet light to produce different organic products, including those shown in Table 5.1.

Table 5.1

structure of product	systematic name of product
$CH_3(CH_2)_5Cl$	
$CH_3(CH_2)_3CHClCH_3$	
$CH_3(CH_2)_3CHClCH_2Cl$	1,2-dichlorohexane
$CH_3(CH_2)_{10}CH_3$	dodecane
$CH_3(CH_2)_3CH(CH_3)CH(CH_3)(CH_2)_3CH_3$	5,6-dimethyldecane

(a) Complete Table 5.1. [2]

(b) The mechanism for the reaction of hexane with $Cl_2(g)$ involves three stages.

stage 1 initiation
stage 2 propagation
stage 3 termination

In stage 1 and 2, free radicals are produced.

(i) Describe what is meant by free radical.

.....

..... [1]

(ii) Name the type of bond breaking that occurs to produce the free radical •Cl from Cl_2.

..... [1]

(iii) Suggest a reaction sequence of **two** propagation reactions that result in $CH_3(CH_2)_4CH_3$ forming $CH_3(CH_2)_3CHClCH_3$.

propagation reaction 1

$CH_3(CH_2)_4CH_3$ + Cl• → $CH_3(CH)_4CH_2$• + HCl

propagation reaction 2

$CH_3(CH)_4CH_2$• + Cl_2 → $CH_3(CH_2)_3CHClCH_3$ + Cl•

[2]

(iv) Suggest a reaction sequence of **one** propagation reaction followed by a termination reaction that results in $CH_3(CH_2)_4CH_3$ forming $CH_3(CH_2)_{10}CH_3$.

propagation reaction

$CH_3(CH_2)_4CH_3$ ..... → .....

termination reaction

..... → $CH_3(CH_2)_{10}CH_3$

[2]

(c) The proportion of each product varies depending on the type of free radical intermediate that is produced.

Table 5.2

primary free radical	secondary free radical	tertiary free radical
$\cdot C(CH_3)H_2$	$\cdot C(CH_3)_2H$	$\cdot C(CH_3)_3$
→ increased stability of radical		

Use Table 5.2 to suggest which factor determines the increased stability of free radicals from primary to secondary to tertiary.

.....

..... [1]

[Total: 9]

6 (a) Figure 6.1 shows the structure of compound **P**.

P

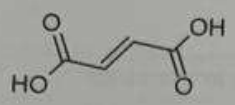
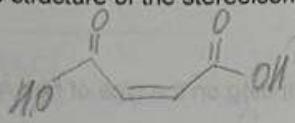


Figure 6.1

(i) Draw the structure of the stereoisomer of **P**.



[1]

(ii) Explain why **P** shows stereoisomerism.

.....

.....

..... [2]

(b) **P** reacts to produce compound **Q**.

P **Q**

Figure 6.2

(i) Identify the reagent and conditions required to convert **P** to **Q**.

reagent .....

conditions .....

[2]

(ii) Complete Figure 6.3 to show the pair of stereoisomers of **Q**.

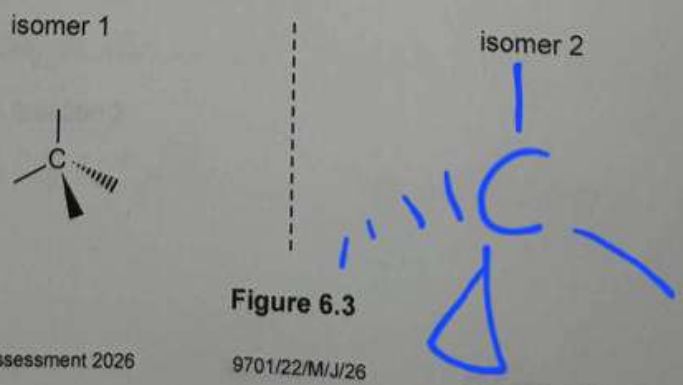


Figure 6.3

[2]