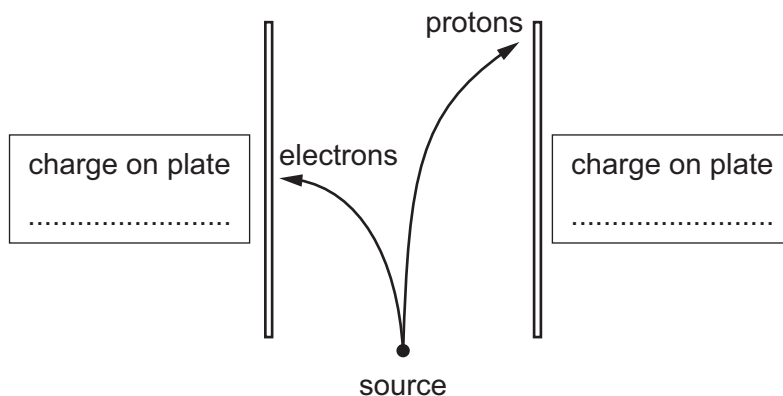


Answer **all** the questions in the spaces provided.

- 1** Atoms contain the subatomic particles electrons, protons and neutrons. Protons and electrons were discovered by observations of their behaviours in electric fields.

- (a)** The diagram shows the behaviour of separate beams of electrons and protons in an electric field.

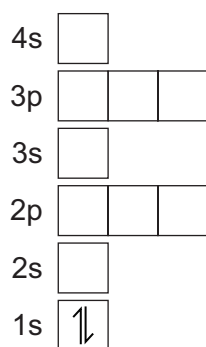


- (i)** Complete the diagram with the relative charge of each of the electrically charged plates. [1]
- (ii)** On the diagram, draw a line to show how a separate beam of neutrons from the same source behaves in the same electric field. [1]
- (b)** Electrons in atoms up to $_{36}\text{Kr}$ are distributed in s, p and d orbitals.
- (i)** State the number of occupied orbitals in an isolated atom of $_{36}\text{Kr}$.

type of orbital	s	p	d
number of orbitals			

[3]

- (ii) Complete the diagram to show the number and relative energies of the electrons in an isolated atom of $_{14}\text{Si}$.



[2]

- (iii) The diagram shows a type of orbital.



State the total number of electrons that exist in all orbitals of this type in an atom of $_9\text{F}$.

..... [1]

- (iv) The first ionisation energies of elements in the first row of the d block ($_{21}\text{Sc}$ to $_{29}\text{Cu}$) are very similar. For all these elements, it is a 4s electron that is lost during the first ionisation.

Suggest why the first ionisation energies of these elements are very similar.

.....

.....

.....

..... [3]

- (c) *Hydron* is a general term used to represent the ions $^1_1\text{H}^+$, $^2_1\text{H}^+$ and $^3_1\text{H}^+$.

State, in terms of subatomic particles in the nucleus, what is the same about each of these ions and what is different.

same

different

[1]

[Total: 12]

2 The Period 3 elements, Na to S, all react with oxygen to form oxides.

(a) State the trend in acid/base behaviour of the oxides of the Period 3 elements, from Na to S.

.....
 [1]

(b) State and explain the trend, from Na to S, in the maximum oxidation number of the Period 3 elements in their oxides.

.....

 [2]

(c) Sodium oxide and phosphorus(V) oxide both react with water.

Name the product of each reaction.

reaction	product
sodium oxide with water	
phosphorus(V) oxide with water	

[2]

(d) Explain why phosphorus(V) oxide has a low melting point of approximately 300 °C but magnesium oxide has a high melting point of approximately 2850 °C.

.....

 [3]

(e) Aluminium oxide, Al_2O_3 , reacts separately with both acids and alkalis.

(i) Write an equation for the reaction of aluminium oxide with excess aqueous hydrochloric acid.

..... [1]

(ii) Write an equation for the reaction of aluminium oxide with excess aqueous sodium hydroxide.

..... [1]

(f) Describe the lattice structure of silicon(IV) oxide.

Your answer should include reference to the arrangement of the silicon and oxygen atoms and the bonds between them.

.....

 [2]

(g) Sodium oxide and silicon(IV) oxide react to form sodium silicate(IV), Na_2SiO_3 .

Sodium oxide is obtained from the thermal decomposition of sodium carbonate.

Write equations for the following reactions:

(i) sodium oxide with silicon(IV) oxide

..... [1]

(ii) the thermal decomposition of sodium carbonate, forming sodium oxide and carbon dioxide.

..... [1]

[Total: 14]

3 PCl_5 , PCl_3 and NCl_3 are halides of Group 15 elements.

(a) PCl_5 can be formed from the reaction of phosphorus with chlorine. PCl_5 has a melting point of 161°C .

(i) Write an equation for the formation of PCl_5 from the reaction of phosphorus and chlorine.

..... [1]

(ii) State the type of structure and bonding shown by liquid PCl_5 .

..... [1]

(b) A small amount of PCl_5 is added to excess water. The PCl_5 reacts vigorously to form a colourless solution.

(i) Give **one** other observation you would make when PCl_5 reacts with excess water.

..... [1]

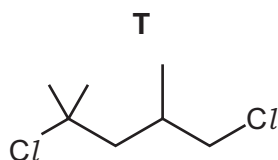
(ii) Write the equation for the reaction of PCl_5 with excess water.

..... [1]

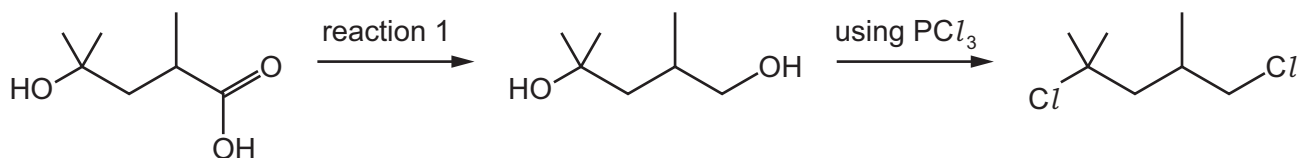
(iii) Estimate the pH of the resulting solution.

..... [1]

(c) PCl_3 is used to convert alcohols to chloroalkanes, such as compound **T**.



A possible synthesis of **T** is shown.

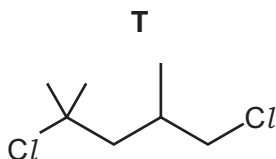


(i) Identify a reagent that could be used in reaction 1.

..... [1]

- (ii) **T** exhibits optical isomerism.

Explain what is meant by the term *optical isomer* and circle any atom(s) in **T** that give rise to optical isomerism.



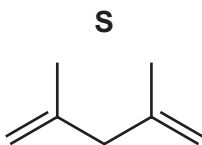
.....

.....

.....

[2]

- (iii) **T** is a **minor** product in the reaction of compound **S** with excess HCl.



Draw the structure of the **major** product of the reaction of **S** with excess HCl.

[1]

(d) NCl_3 is a yellow liquid that can be used to bleach flour.

(i) Predict the shape of the NCl_3 molecule and the Cl-N-Cl bond angle.

shape

bond angle [2]

(ii) NCl_3 reacts with water to form HOCl , a weak Brønsted-Lowry acid.

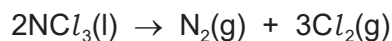
Explain fully what is meant by the term *weak Brønsted-Lowry acid*.

.....

.....

..... [2]

(iii) $\text{NCl}_3(\text{l})$ decomposes according to the equation shown.



A sealed container of volume 250 cm^3 contains an unreactive gas at a pressure of $1.00 \times 10^5 \text{ Pa}$.

0.241 g of $\text{NCl}_3(\text{l})$ was injected into the sealed container.

The sealed container was heated to make the $\text{NCl}_3(\text{l})$ decompose fully and then cooled to 20°C .

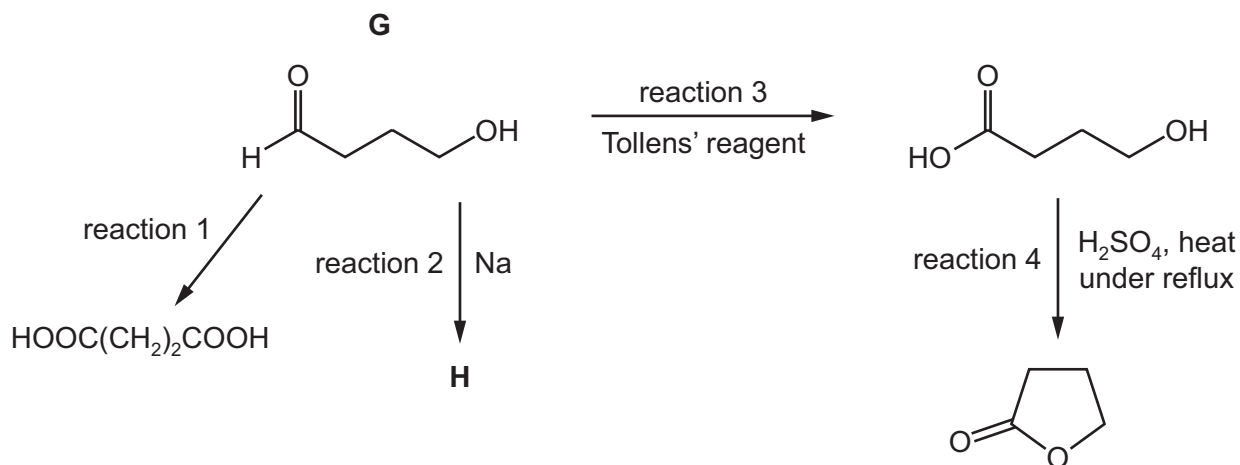
Calculate the final **total** pressure inside the sealed container at 20°C after the $\text{NCl}_3(\text{l})$ has fully decomposed.

final **total** pressure = Pa
[4]

[Total: 17]



4 Some reactions of compound **G** are shown.



(a) (i) State the type of reaction that occurs in reaction 1.

..... [1]

(ii) Suggest the reagent(s) and conditions required for reaction 1.

.....

..... [2]

(iii) Draw the structure of the organic product, **H**, from reaction 2.

[1]

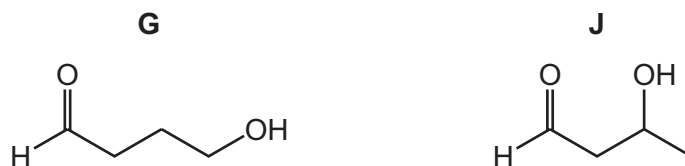
(iv) State what you would observe in reaction 3.

..... [1]

(v) Give the type of reaction shown by reaction 4.

..... [1]

(b) **G** and **J** are structural isomers of each other.



(i) Name the type of structural isomerism shown by **G** and **J**.

..... [1]

(ii) Suggest **one** chemical test that can distinguish **G** from **J**. Give the result of the test with each compound.

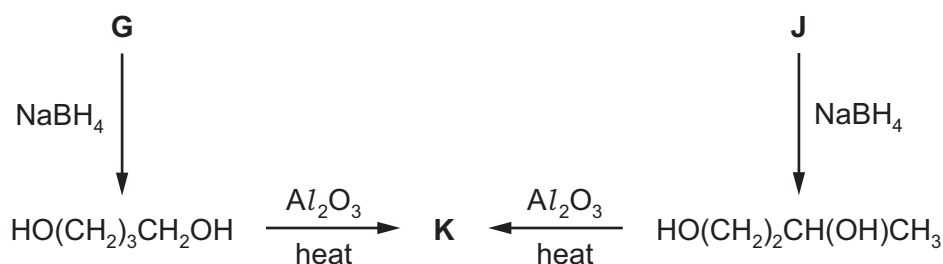
test

result with **G**

result with **J**

[2]

In the reaction schemes below, **G** and **J** are converted into organic compound **K**.



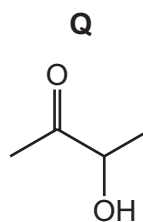
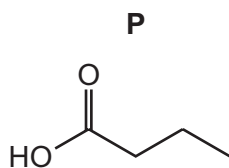
(iii) State the role of NaBH₄ in the reactions with **G** and **J**.

..... [1]

(iv) Identify the organic product **K**.

..... [1]

(c) **P** and **Q** have the same molecular formula as **G**.

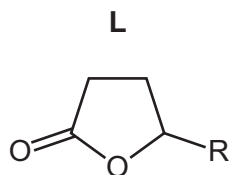


Complete the table with the expected observations for the reactions of **P** and **Q** with the named reagents.

reagent	result with P	result with Q
$\text{Br}_2(\text{aq})$		
2,4-dinitrophenylhydrazine		
aqueous sodium carbonate		

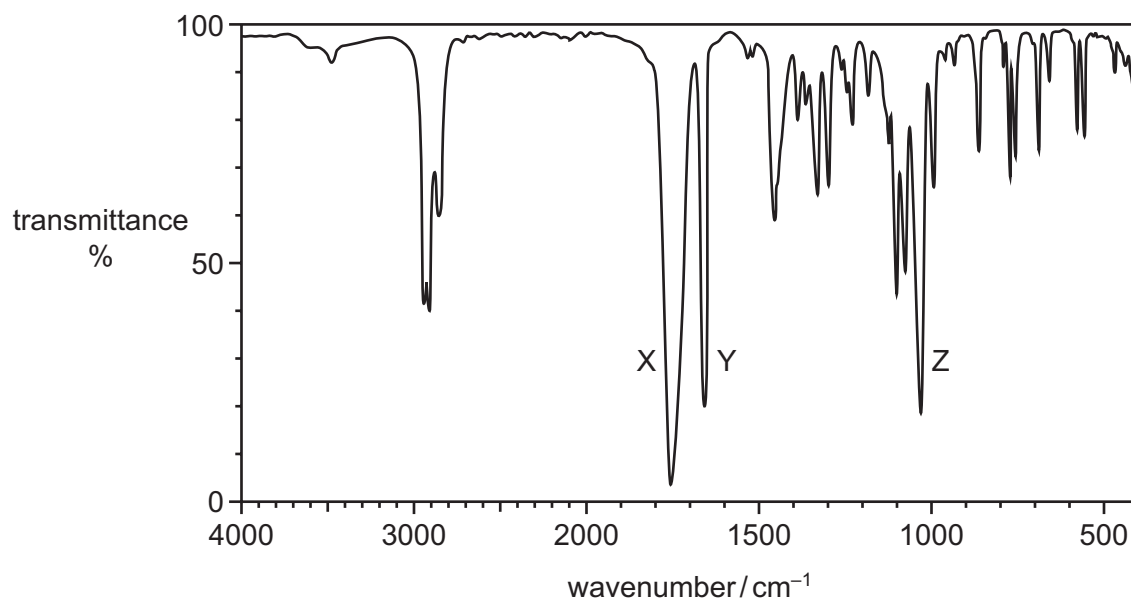
[3]

(d) The structure of compound **L** is shown. R represents a hydrocarbon chain.



A student was asked to deduce the full structure of **L**.

The student analysed **L** using infrared spectroscopy. The following spectrum was obtained.



(i) Identify the bonds responsible for the absorptions marked X and Z.

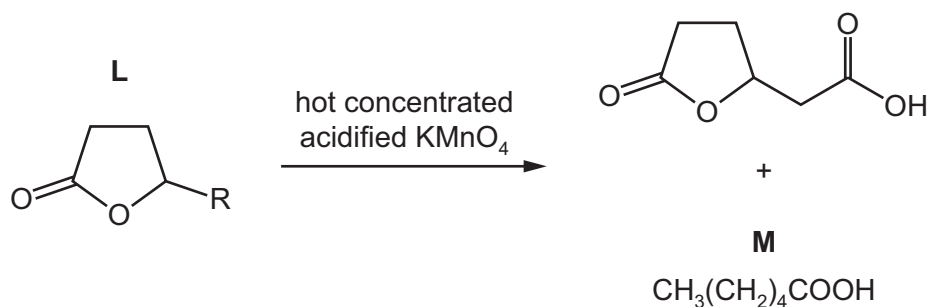
X

Z

[1]

Absorption Y shows that **L** has a C=C bond present in the R group.

The student decided to treat **L** with hot concentrated acidified potassium manganate(VII). The products of the reaction are shown.



(ii) Name **M**.

..... [1]

(iii) Use the information in (d) to deduce the molecular formula of **L**.

molecular formula of **L** = [1]

[Total: 17]





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