# Question - 01



This question is about metals and their compounds.

(a) State why the atomic radius of calcium is greater than the atomic radius of magnesium.

_____

_____

_____

**(1)**

(b) Magnesium reacts with steam.

Give an equation, including state symbols, for this reaction.

_____

**(1)**

(c) Similar-sized pieces of barium and magnesium are added to separate 100 $cm^3$ samples of dilute sulfuric acid. In each case the sulfuric acid is in excess.

The barium reacts quickly at first. After a few minutes the reaction stops, even though there is still some unreacted barium in the flask.

The magnesium reacts more slowly than the barium, but the reaction continues until all the magnesium has reacted.

Explain why

- the barium initially reacts more quickly than the magnesium
- the barium reaction stops before all the barium has reacted.

_____

_____

_____

_____

_____

_____

**(3)**

(d) A metal nitrate **X**$(NO_3)_2$ completely decomposes when heated.

$$2\ \mathbf{X}(NO_3)_2(s) \rightarrow 2\ \mathbf{X}O(s) + 4\ NO_2(g) + O_2(g)$$

A 0.832 g sample of **X**$(NO_3)_2$ decomposes on heating to produce a total of 348 $cm^3$ of gas at 298 K and 100 kPa

Deduce the identity of metal **X**.

The ideal gas constant, $R = 8.31\ J\ K^{-1}\ mol^{-1}$

Identity of metal **X** _____

**(6)**

(e) Sodium reacts with aluminium and hydrogen to form solid $NaAlH_4$

Give an equation for this reaction.

Suggest why $NaAlH_4$ has a high melting point.

Equation

_____

Suggestion _____

_____

_____

_____

**(3)**

(f) Give the equation for the reaction between $H_3PO_4$ and an excess of NaOH

**(1)**

Lithium is an important metal used in cells to power mobile phones.

(g) In a lithium cell, a lithium cobalt oxide electrode and a lithium electrode are used.

Give the equation for the reaction that occurs at the positive electrode.

_____

**(1)**

(h) Commercial electrochemical cells can be rechargeable or non-rechargeable.

State why lithium cells can be recharged.

_____

_____

**(1)**

(a) More shells
OR
more energy levels.

*Allow Ca has 4 shells and Mg has 3 shells*
*Do not accept more outer shells*
*Ignore shielding*
*Ignore subshells/orbitals/more electrons*

**1**

(b) $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$

*State symbols required*
*Allow multiples*

**1**

(c) **M1** (Ba is more reactive) because outer/valence electrons further from nucleus/less attracted to the nucleus/lost more easily

**M2** Insoluble barium sulfate (is formed)
OR
$Ba + H_2SO_4 \rightarrow BaSO_4(s) + H_2$
M3 Barium sulfate prevents further reaction (with sulfuric acid)
OR
Barium gets coated with barium sulfate (so no more barium reacts)

**3**

(d) **M1** P = 100 000 Pa and V = $348 \times 10^{-6}$ $m^3$

M2 $n = \frac{PV}{RT}$ or $\frac{100\,000 \times 348 \times 10^{-6}}{8.31 \times 298}$

**M3** n = 0.01405 mol

M4 n metal nitrate = $0.01405 \times \frac{2}{5} = 5.62 \times 10^{-3}$ mol

M4 = M3 x $\frac{2}{5}$

M5 $M_r$ metal nitrate = $\frac{0.832}{5.62 \times 10^{-3}} = 148(.0)$

*M5 = 0.832 ÷ M4*

**M6** $A_r$ of metal = 148.0 - (2 × 14 +2 × 48) = 24(.0) = Mg

*M6 = M5 - 124* ***and*** *identity of a metal with 2+ oxidation state*

**6**

(e) **M1** $Na + Al + 2\ H_2 \rightarrow NaAlH_4$

**M2** contains oppositely charged ions/ $Na^+$ and $AlH_4^-$ ions

**M3** strong attraction between (oppositely charged) ions

**3**

(f) $3\ NaOH + H_3PO_4 \rightarrow Na_3PO_4 + 3\ H_2O$

*Allow multiples and ignore state symbols*

**1**

(g) $Li^+ + CoO_2 + e^- \rightarrow Li^+(CoO_2)^-$

*Allow $Li(CoO_2)$ as product*

1

(h) The electrode reactions can be reversed (by applying a reverse potential)

*Allow reaction is reversible (by applying a reverse potential)*

1

**End of Question**

# Question - 02



This question is about chlorine.

(a) Give an equation to show how chlorine forms an acidic solution in water.

_____

**(1)**

(b) Give an equation for the reaction between chlorine and cold, dilute aqueous sodium hydroxide.

_____

**(1)**

(c) In acidic conditions, $ClO_3^-$ ions oxidise $Cl^-$ ions to form $Cl_2$

Deduce a half-equation for the oxidation of $Cl^-$ to $Cl_2$

Deduce a half-equation for the reduction of $ClO_3^-$ to $Cl_2$

Deduce the overall equation for this reaction.

Half-equation for the oxidation of $Cl^-$ to $Cl_2$

_____

Half-equation for the reduction of $ClO_3^-$ to $Cl_2$

_____

Overall equation

_____

**(3)**

(d) Give the equation for the reaction of solid sodium chloride with concentrated sulfuric acid.

State the role of the chloride ions in this reaction.

Equation

_____

Role _____

**(2)**

(e) Draw the shape of the $Cl_3^-$ ion.
Include any lone pairs of electrons that influence the shape.

**(1)**

(f) Chlorine forms an ion with the Group 3 element thallium (Tl).

State and explain the bond angle in $TlCl_2^+$

Bond angle _____

Explanation _____

_____

_____

_____

**(2)**

(a) $Cl_2 + H_2O \rightleftharpoons HCl + HOCl$

*Allow →*

OR

$2\ Cl_2 + 2\ H_2O \rightarrow 4\ HCl + O_2$

*Allow multiples*

**1**

(b) $Cl_2 + 2\ NaOH \rightarrow NaCl + NaOCl + H_2O$

*Allow multiples*

**1**

(c) **M1** $2\ Cl^- \rightarrow Cl_2 + 2\ e^-$

*Allow multiples*

**M2** $2\ ClO_3^- + 12\ H^+ + 10\ e^- \rightarrow Cl_2 + 6\ H_2O$

**M3** $2\ ClO_3^- + 12\ H^+ + 10\ Cl^- \rightarrow 6\ Cl_2 + 6\ H_2O$

*M3 Allow*
*$ClO_3^- + 6\ H^+ + 5\ Cl^- \rightarrow 3\ Cl_2 + 3\ H_2O$*

**3**

(d) $NaCl + H_2SO_4 \rightarrow HCl + NaHSO_4$

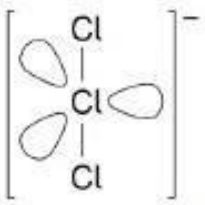
OR

$2\ NaCl + H_2SO_4 \rightarrow 2\ HCl + Na_2SO_4$

Base/proton acceptor

**2**

(e)




*Ignore absence of minus sign*

**1**

(f) 180°

(2) bond pairs repel to be as far apart as possible

*Allow (2) bond pairs repel equally*
*Ignore linear*

**2**

# Question - 03



Which substance contains delocalised electrons?

A cyclohexane ⬭

B graphite ⬭

C iodine ⬭

D sodium chloride ⬭

B

*graphite*

**End of Question**

# Question - 04



Which statement about $(CH_3)_2CHCH_2COOH$ is correct?

**A** In aqueous solution it reacts with magnesium to form carbon dioxide. ○

**B** It can form hydrogen bonds. ○

**C** It has optical isomers. ○

**D** It has the IUPAC name 2-methylbutanoic acid. ○

B

*It can form hydrogen bonds.*

**End of Question**

Which molecule has a permanent dipole?

**A** $BF_3$ ⬭

**B** $NH_3$ ⬭

**C** $SiCl_4$ ⬭

**D** $SO_3$ ⬭

B

$NH_3$

# Question - 06



In which molecule are all the atoms in the same plane?

A $CH_3CHO$ ⬭

B $CH_3NH_2$ ⬭

C $C_6H_5Cl$ ⬭

D $C_6H_5CH_3$ ⬭

C

$C_6H_5Cl$

**End of Question**

# Question - 07



In which substance do covalent bonds break when it melts?

A hexane ○

B ice ○

C iodine ○

D silicon dioxide ○

D

*silicon dioxide*

**End of Question**

# Question - 08



Which species has a lone pair of electrons on the central atom?

A $CO_2$ ⬭

B $SO_2$ ⬭

C $PCl_6^-$ ⬭

D $SO_4^{2-}$ ⬭

B

$SO_2$

**End of Question**

# Question - 09



Which statement about inorganic ionic compounds is **always** correct?

**A** They dissolve in water to give neutral solutions. ⬭

**B** They release energy when they melt. ⬭

**C** They contain metal cations. ⬭

**D** They form giant structures. ⬭

D

*They form giant structures.*

**End of Question**

# Question - 10



This question is about elements in Period 3 and their compounds.

(a) When a piece of sodium is added to 200 $cm^3$ of water in a large beaker a vigorous reaction occurs. The temperature of the water increases by 25 °C

Give an equation, including state symbols, for the reaction of sodium with water.

Suggest why it is dangerous to react a similar piece of sodium with 10 $cm^3$ of water in a boiling tube.

Equation

_____

Why it is dangerous _____

_____

_____

**(2)**

(b) Give an equation for the reaction of phosphorus(V) oxide with water.

Suggest a pH for the solution formed.

Equation

_____

pH _____

**(2)**

(c) Explain, in terms of crystal structure and bonding, why silicon(IV) oxide has a higher melting point than phosphorus(V) oxide.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

**(4)**



(d) An element in Period 3 forms an oxide that is insoluble in water.
This oxide reacts with sulfuric acid and with aqueous potassium hydroxide.

Give the formula for this oxide.

Give an equation for the reaction of this oxide with sulfuric acid.

Formula _____

Equation

_____

**(2)**

(e) Give the formula of a hydroxide of an element in Period 3 used in medicine.

_____

**(1)**

(f) Identify the element in Period 3, from sodium to chlorine, that has the largest atomic radius.

_____

**(1)**

(a) $2\ Na(s) + 2\ H_2O(l) \rightarrow 2\ NaOH(aq) + H_2(g)$

*Allow ionic equations*

*Allow multiples*

1

Temperature will go up more **or** reactants can shoot out of the tube

*Allow the mixture could explode or glass could shatter or hydrogen could ignite/is flammable*

*Ignore reaction is exothermic/vigorous*

1

(b) $P_4O_{10} + 6\ H_2O \rightarrow 4\ H_3PO_4$

*Allow ionic equations*

1

Allow –1 to + 1

*Do not allow equations from $P_2O_5$*

1

(c) M1 $SiO_2$ is macromolecular / giant covalent / giant molecule

*Do not allow giant, giant atomic or giant ionic*

1

M2 Strong <u>covalent</u> bonds (between atoms) or <u>covalent</u> bonds need a lot of energy to be broken/overcome

1

M3 $P_4O_{10}$ is <u>molecular</u> or <u>simple covalent molecule</u>

1

M4 Weak van der Waals forces <u>between molecules</u> or van der Waals forces <u>between molecules</u> break easily

1

(d) $Al_2O_3$

1

$Al_2O_3 + 3\ H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3\ H_2O$
or $Al_2O_3 + 6\ H^+ \rightarrow 2\ Al^{3+} + 3\ H_2O$

1

(c) $Mg(OH)_2$

1

(f) Na / sodium

1

# Question - 11



Which pair of reagents reacts to form a tetrahedral complex?

A $CoCl_2(aq)$ and concentrated $NH_3(aq)$ ○

B $CuSO_4(aq)$ and concentrated $NH_3(aq)$ ○

C $CuSO_4(aq)$ and sodium ethanedioate(aq) ○

D $FeCl_3(aq)$ and concentrated $HCl(aq)$ ○

**D**

*$FeCl_3(aq)$ and concentrated $HCl(aq)$*

**End of Question**

Which substance has **no** delocalised electrons?

A graphite ⬭

B methylbenzene ⬭

C poly(propene) ⬭

D sodium ⬭

**C**

*poly(propene)*

**End of Question**

# Question - 13



This question is about some elements in Group 7 and their compounds.

(a) Chlorine is added to some drinking water supplies to decrease the risk of people suffering from diseases such as cholera.

State why the amount of chlorine added must be controlled.

_____

_____

**(1)**

(b) Give an equation for the reaction of chlorine with water to form a solution containing **two** acids.

Explain, with reference to electrons, why this is a redox reaction.

Equation

_____

Explanation _____

_____

_____

_____

**(2)**

(c) A student bubbles chlorine gas through a solution of sodium iodide.

State the observation the student would make.

Give an ionic equation for the reaction.

Observation _____

Ionic equation

_____

**(2)**

(d) The student adds a few drops of concentrated sulfuric acid to a small amount of solid sodium iodide.

**Two** gaseous sulfur-containing products are formed.

Give an equation for the formation of each of these sulfur-containing products.

State the role of sulfuric acid in the formation of these products.

Equation 1

_____

Equation 2

Role _____

**(3)**

(e) The student adds a few drops of acidified silver nitrate solution to a solution of an unknown **impure** sodium halide.
The student observes bubbles of gas and a colourless solution.
The student bubbles the gas through calcium hydroxide solution and a white precipitate forms.

Deduce the identity of the sodium halide.

Suggest the identity of the gas.

Give an ionic equation for the formation of this gas from the impurity.

Identity of sodium halide _____

Identity of gas _____

Ionic equation

_____

**(3)**

(f) The $ClF_2^+$ ion contains two different Group 7 elements.

Use your understanding of the electron pair repulsion theory to draw the shape of this ion.

Include any lone pairs of electrons that influence the shape.

Explain why the ion has the shape you have drawn.

Suggest a value for the bond angle in the ion.

Shape

Explanation _____

_____

_____

Bond angle _____

**(3)**

(g) Magnesium is used in the extraction of titanium from titanium(IV) chloride.



Give an equation for this reaction.

_____

**(1)**

(a) toxic/poisonous/too much chlorine causes death

1

(b) $Cl_2 + H_2O \rightarrow HCl + HClO$

*allow* $Cl_2 + H_2O \rightarrow 2\,H^+ + Cl^- + ClO^-$

1

chlorine/Cl/$Cl_2$ gains electron(s) (to form $Cl^-$) **and** loses electron(s) (to form $ClO^-$)

1

*ignore chlorine is oxidised and reduced*
*ignore disproportionation*
*ignore oxidation numbers unless incorrect*

(c) brown solution **or** black solid (forms)

*do **not** accept purple*

1

$Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$

*allow multiples*
*ignore state symbols*

1

(d) $H_2SO_4 + 2H^+ + 2I^- \rightarrow SO_2 + 2H_2O + I_2$

*allow* $SO_4^{2-} + 4H^+ + 2I^- \rightarrow SO_2 + 2H_2O + I_2$

1

$H_2SO_4 + 8H^+ + 8I^- \rightarrow H_2S + 4H_2O + 4I_2$

*allow* $SO_4^{2-} + 10H^+ + 8I^- \rightarrow H_2S + 4H_2O + 4I_2$

1

oxidising agent

1

*equations can be in either order*
*allow alternative correct balanced equations starting from NaI to form* $SO_2$ *and* $H_2S$

*eg*
$2\,H_2SO_4 + 2\,NaI \rightarrow Na_2SO_4 + SO_2 + 2\,H_2O + I_2$
$3\,H_2SO_4 + 2\,NaI \rightarrow 2\,NaHSO_4 + SO_2 + 2\,H_2O + I_2$
$5\,H_2SO_4 + 8\,NaI \rightarrow 4\,Na_2SO_4 + H_2S + 4\,H_2O + 4I_2$
$9\,H_2SO_4 + 8\,NaI \rightarrow 8\,NaHSO_4 + H_2S + 4\,H_2O + 4I_2$

(e) NaF **or** sodium fluoride

1

$CO_2$ **or** carbon dioxide

1

$CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$

*allow multiples*

1

(f)


*Allow shape with 2 lp and 2 bp*

*ignore absence of charge*

1

lone pair–lone pair repulsion > bond pair–bond pair repulsion

**or**

lone pair repel to be as far apart as possible

*allow lp–lp repulsion > bp–bp repulsion*

1

104 to 106(°)

*allow 95 to 106(°)*

1

(g) $TiCl_4 + 2Mg \rightarrow 2MgCl_2 + Ti$

*allow multiples*

*ignore state symbols*

1

# Question - 14

This question is about Period 3 elements and their compounds.

(a) Which is **not** a correct statement about magnesium hydroxide?

Tick (✓) **one** box.

It is used to neutralise stomach acid ☐

It forms a solution with pH = 14 at 25 °C ☐

It has the empirical formula $H_2MgO_2$ ☐

**(1)**

(b) Give an equation for the reaction of aluminium oxide with sulfuric acid.

_____

**(1)**

(c) Identify a reagent or test that could be used to distinguish between aqueous solutions of sulfur dioxide and sulfur trioxide with the same concentrations.

State the observation in each case.

Reagent or test _____

Observation with sulfur dioxide solution _____

_____

Observation with sulfur trioxide solution _____

_____

**(3)**

(d) The mass spectrum of the element phosphorus has a peak at $\frac{m}{z} = 124$

Give the formula of the species responsible for this peak.

_____

**(2)**

(e) Give an equation for the reaction of phosphorus(V) oxide with sodium hydroxide solution.

_____

**(1)**

(f) Draw the displayed formula of the molecule formed when phosphorus(V) oxide reacts with water.

**(1)**

(g) The table below shows the melting points of three substances.

| Substance | Melting point / K |
|---|---|
| sodium chloride | 1074 |
| chlorine | 172 |
| hydrogen chloride | 158 |

Explain why the melting points of these substances are different

You should refer to the structure of and bonding in each substance.

**(6)**

(a) forms a solution with pH = 14 at 25°C

*auto*

1

(b) $Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$

*allow multiples*

*ignore state symbols*

1

(c) universal indicator

1

$SO_2$(aq) orange-red

1

$SO_3$(aq) red

1

*allow correct comparison of acidic colours (red, orange, yellow)*

**or**

pH meter

$SO_2$(aq) pH 2-3

$SO_3$(aq) pH 0-1

*allow correct comparison of acidic pH ignoring values*

**or**

any named metal carbonate (**or** formula) **or** Mg **or** Ca **or** Zn

$SO_2$(aq) slower effervescence

$SO_3$(aq) faster effervescence

*if reagent is incomplete lose M1 and mark on*

*allow observation*

*allow correct comparison*

*allow named oxidising agent*

*eg (acidified) $KMnO_4$ **or** (acidified) $K_2Cr_2O_7$*

*$SO_2$(aq) correct colour acidified change*

*$SO_3$(aq) no visible change **or** NVC*

*allow (acidified) barium chloride solution*

***or** allow (acidified) barium chloride solution*

*$SO_2$(aq) no visible change **or** NVC*

*$SO_3$(aq) white precipitate*

(d) $^{31}P_4^+$

*Allow $P_4^+$ = 1 mark*

*Allow $^{31}P$ = 1 mark*

**2**

(e) $P_4O_{10} + 12\ NaOH \rightarrow 4\ Na_3PO_4 + 6\ H_2O$

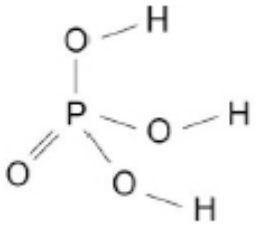
*allow formation of acid salts*

*$P_4O_{10} + 4\ NaOH + 2\ H_2O \rightarrow 4\ NaH_2PO_4$*

*$P_4O_{10} + 8\ NaOH \rightarrow 4\ Na_2HPO_4 + 2\ H_2O$*

**1**

(f)




*must show all bonds*

**1**

(g) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

| | |
|---|---|
| **Level 3**<br>**5-6 marks** | All stages are covered and the description of each stage is generally correct and virtually complete.<br>Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 and stage 3. |
| **Level 2**<br>**3-4 marks** | All stages are covered but the description of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.<br>Answer is mainly coherent and shows progression from stage 1 to stage 2 and/or stage 3. |
| **Level 1**<br>**1-2 marks** | Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete.<br>Answer includes isolated statements and these are presented in a logical order. |
| **0 marks** | Insufficient correct chemistry to gain a mark. |

*indicative chemistry content*

*contradictions negate statements*

Stage 1 **structure**

1a NaCl ionic lattice **or** giant ionic

1b $Cl_2$ **and** HCl molecular (covalent)
**or**
$Cl_2$ **and** HCl (simple) molecules

Stage 2 **forces responsible for melting point**

2a NaCl attractions between + and – ions

2b $Cl_2$ vdw forces

2c HCl dipole dipole forces

Stage 3 **comparison of melting point**

3a ionic bonds stronger than IMF

3b chlorine/$Cl_2$ is a bigger (molecule) than HCl
**or**
chlorine/$Cl_2$ has more electrons than HCl

3c more/stronger forces between molecules in $Cl_2$ than those in HCl
**or**
more/stronger IMF in $Cl_2$ than those in HCl
**or**
vdw between molecules in $Cl_2$ > dipole dipole between molecules in HCl

# Question - 15



What happens when water is vaporised?

**A** Covalent bonds break within molecules. ○

**B** Intermolecular forces are overcome. ○

**C** The enthalpy of the molecules decreases. ○

**D** The disorder of the molecules decreases. ○

B

*Intermolecular forces are overcome.*

**End of Question**

# Question - 16



Which substance has significant electron delocalisation?

A graphite ⬭

B iodine ⬭

C sodium chloride ⬭

D tetrachloromethane ⬭

A

*graphite*

**End of Question**

# Question - 17



The molar enthalpy of vaporisation ($\Delta H_{vap}$) of a liquid is the enthalpy change when one mole of liquid is converted to vapour at the boiling point of the liquid.

A student does an experiment to determine $\Delta H_{vap}$ for water.

The student:

- places a large beaker on a balance
- pours 500 $cm^3$ of water into the beaker
- uses a 2.4 kW heater to raise the temperature of the water to 100 °C
- records the mass of the beaker and hot water
- uses the 2.4 kW heater to boil the water for 100 s
- records the mass of the beaker and remaining water.

The loss in mass is 103 g

(a) Calculate $\Delta H_{vap}$ for water.

[1 kW = 1 kJ $s^{-1}$]

$\Delta H_{vap}$ _____ kJ $mol^{-1}$

**(3)**

The table below shows some data about three compounds that all contain the same number of electrons.

| **Compound** | $CH_3CH_2OH$ | $CH_3CH_2NH_2$ | $CH_3OCH_3$ |
|---|---|---|---|
| **Boiling point / K** | 352 | 290 | 248 |

(b) All three compounds in the table above are polar.
Ethanol is the most polar and ethylamine is the least polar.

Explain why all three molecules are polar and why ethylamine is the least polar.
In your answer refer to the shapes around, and relative electronegativities of, the most electronegative atoms.

_____

_____

**(4)**

(c) Explain the trend in the boiling points of the three compounds.
Refer to the intermolecular forces in all three compounds in your answer.

**(3)**

(a) **M1** energy transferred = 2.4 x 100 (= 240 kJ / 240000 J)

***M1 IGNORE*** *sign*

**M2** amount of water vaporised = $\frac{103}{18}$ (= 5.72 mol)

**M3** $\Delta H_{vap} = \frac{\text{M1 in kJ}}{\text{M2}}$ = (+)41.9 / 42.0 (kJ mol$^{-1}$)

***ALLOW*** *ecf in* ***M3*** *(if q = mcΔT used for incorrect* ***M1*** *then a value* ***in kJ*** *could score ecf in* ***M3****)*

***ALLOW*** *41.9 to 42.11 to two or more sig figs*

***M3 NOT*** *if negative*

*Correct answer = 3 marks*

**3**

(b) **M1** O **AND** N more electronegative than C and/or H (so all have polar bonds)

**M2** $CH_3CH_2OH$ and $CH_3OCH_3$ both v-shaped/non-linear/bent **AND** $CH_3CH_2NH_2$ (trigonal) pyramidal

**M3** shapes are not symmetrical (so molecules are polar)

**M4** O more electronegative than N (so ethylamine is least polar)

***ALLOW*** *'different electronegativities' PLUS diagrams labelled δ+ and δ-*

***ALLOW*** *angular for v-shaped in* ***M2***

*Diagrams from* ***M2*** *do not require lone pairs*

***ALLOW M3*** *if diagrams in* ***M2*** *show asymmetry*

*Correct diagrams of the three shapes gives* ***M2*** *and* ***M3***

**4**

(c) **M1** hydrogen bonding in $CH_3CH_2OH$ and $CH_3CH_2NH_2$ **AND** (permanent) dipole-dipole forces in $CH_3OCH_3$

**M2** hydrogen bonding stronger (than other (intermolecular) forces)

**M3** hydrogen bonding stronger in $CH_3CH_2OH$ than in $CH_3CH_2NH_2$

***IGNORE*** *van der Waals' / temporary/induced dipole-dipole forces*

***M1 NOT*** *any reference to breaking covalent bonds*

***M3 ALLOW*** *reference to O being more/most electronegative (than N) OR ethanol has greater dipole moment / more polar than ethylamine*

*If none of M1, M2 or M3 have been awarded:*

***ALLOW*** *one mark for an indication that higher boiling point = stronger intermolecular forces but*

***NOT*** *if reference to breaking covalent bonds*

**3**

# Question - 18



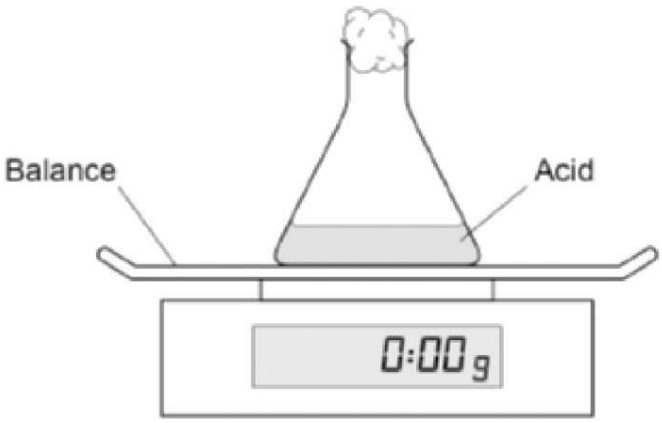
This question is about rates of reaction.

**Figure 1** shows apparatus used to measure the rate of reaction when an acid reacts with an excess of solid sodium hydrogencarbonate, $NaHCO_3$

When different monoprotic organic acids are used, the rates at which gas escapes can be used to compare the strengths of the acids.

A timer is started when the $NaHCO_3$ is added to the acid and the mass of $CO_2$ gas lost is recorded at regular intervals.
(It is assumed that any change in mass is due to the loss of $CO_2$)

**Figure 1**




(a) Suggest a reason why using a conical flask instead of a beaker would give more accurate results in this experiment.

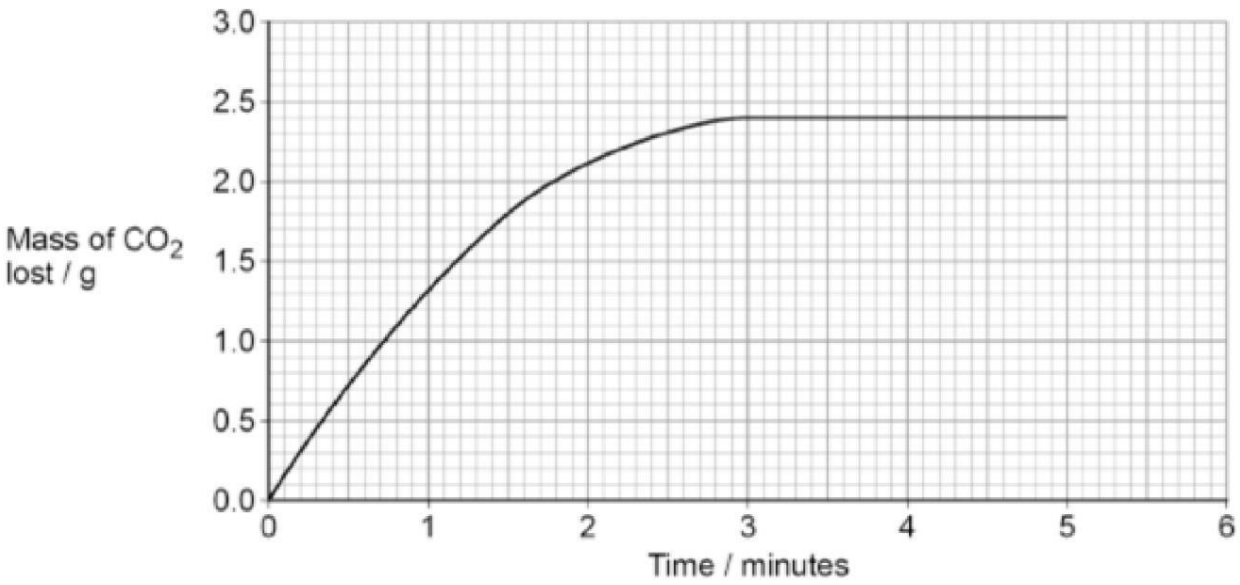
_____

_____

**(1)**

**Figure 2** shows the results of this experiment when 25.0 $cm^3$ of a 2.23 mol $dm^{-3}$ solution of ethanoic acid reacts with an excess of $NaHCO_3$

**Figure 2**




(b) Use **Figure 2** to calculate the rate of reaction at 2 minutes.

Deduce the units of your calculated rate.



Rate _____ Units _____

**(3)**

(c) Chloroethanoic acid is a stronger acid than ethanoic acid.

Sketch, on **Figure 2**, the curve you would expect when 25.0 $cm^3$ of a 2.23 mol $dm^{-3}$ solution of chloroethanoic acid reacts with an excess of $NaHCO_3$

Suggest why chloroethanoic acid is a stronger acid than ethanoic acid.

_____

_____

_____

_____

**(3)**

(a) Reduces loss of liquid droplets

*Allow description of reduction of loss of liquid*

1

(b) M1 Tangent drawn at 2 mins

M2 Gradient of tangent = (0.50 +/- 0.05)

M3 g $min^{-1}$

*Conseq to their M1*

*If convert mins to sec M2 = 7.80 x $10^{-3}$ (7.0 x $10^{-3}$ to 8.6 x $10^{-3}$) and award M3 conseq*

*If M1 not awarded then allow average rate calculated M2 = 1.05*

*If M1 not awarded then allow average rate and if 120 sec used for time allow M2 =0.0175 and can score M3 for g $s^{-1}$*

*Penalise g/min*

3

(c) M1 Curve steeper at first & flattens at same point on y axis

M2 Cl is an electron withdrawing group or negative inductive effect

M3 Weakens the O-H bond / increase polarity of O-H bond

*Allow opposite argument*

*M2 $CH_3$ electron donating or positive inductive effect*

*M3 Makes O-H bond stronger / decrease polarity of O-H bond*

*Also allow answers that discuss the carboxylate ion*

*M2 Cl Electron withdrawing group*

*M3 makes $RCOO^-$ less negative / delocalises the negative charge more / more stable ion (so $RCOO^-$ less likely to accept $H^+$ )*

3

**End of Question**

# Question - 19



This question is about complexes of the transition metal chromium.

(a) State the meaning of the term transition metal complex.

_____

_____

**(1)**

$Cr(PF_3)_6$ is a complex of chromium that contains molecules of $PF_3$

(b) The electron pair repulsion theory can be used to predict the shape of a $PF_3$ molecule.

Draw the shape of a $PF_3$ molecule.
Include any lone pairs of electrons that influence the shape.

Name the shape.

Shape

Name of shape _____

**(2)**

(c) Suggest why the oxidation state of chromium is zero in $Cr(PF_3)_6$

_____

_____

_____

**(1)**

The compound $[Cr(NH_3)_4Cl_2]Cl$ contains ammonia molecules.

(d) Deduce the oxidation state of chromium in $[Cr(NH_3)_4Cl_2]Cl$

_____

**(1)**

(e) Name the type of bond between N and H in ammonia.

_____

**(1)**

(f) The compound $[Cr(NH_3)_4Cl_2]Cl$ contains a complex ion that shows isomerism.

Draw the two isomers of the complex ion.



State the type of isomerism shown.

Isomer 1 Isomer 2

Type of isomerism _____

**(3)**

(g) Complete the equation to show the formation of **one** complex that contains chromium in its +3 oxidation state.

$CrCl_3 + 5\ H_2O \rightarrow$ _____

**(1)**

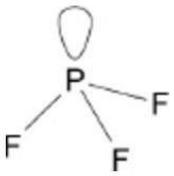
**(Total 10 marks)**

(a) (Central) metal atom/ion surrounded by ligands

*Allow complex in which number of coordinate bonds exceeds oxidation state of the metal*

**1**

(b)




*Allow diagram with 3 bonds and 1 lone pair*

Pyramidal or tetrahedral

*Allow triangular pyramid*

**2**

(c) $PF_3$ is neutral **and** the complex is neutral

*Allow $PF_3$ has no charge **and** the complex has no charge*

*Ignore electronegativity*

**1**

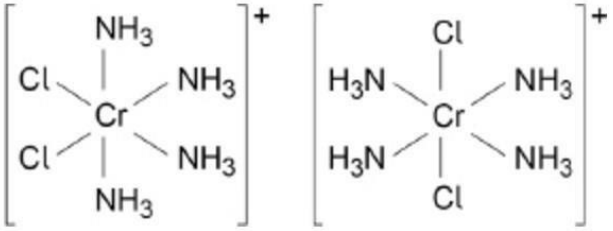
(d) (+)3

**1**

(e) Covalent (bond)

**1**

(f)




*M1 for the two isomers*

*M2 for the charge on the complex ion.*

*Allow 1 mark for one correct isomer with + charge*

Cis-trans/geometric/E-Z isomerism

*Ignore stereoisomerism*

**3**

(g) $[Cr(H_2O)_5Cl]Cl_2$

*Allow $[Cr(H_2O)_5Cl]^{2+}$ + 2 $Cl^-$*

**1**

**[10]**