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CHEMISTRY

9701/21

Paper 2 AS Level Structured Questions

October/November 2016

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

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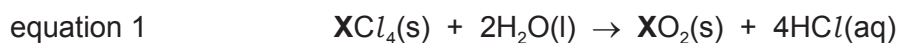
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Answer **all** the questions in the spaces provided.

- 1 A 0.17 g sample of a Group 14 chloride, XCl_4 , reacted with water to produce an oxide, XO_2 , and HCl .



The HCl produced was absorbed in 100 cm^3 of 0.10 mol dm^{-3} sodium hydroxide solution (an excess).

In a titration, the unreacted sodium hydroxide solution required 30.0 cm^3 of 0.20 mol dm^{-3} hydrochloric acid for complete neutralisation.

- (a) Calculate the amount, in moles, of hydrochloric acid used in the titration to neutralise the unreacted sodium hydroxide solution.

amount = ... mol [1]

- (b) Write the equation for the reaction between hydrochloric acid and sodium hydroxide.

..... [1]

- (c) Calculate the amount, in moles, of sodium hydroxide neutralised in the titration.

amount = ... mol [1]

- (d) Calculate the amount, in moles, of sodium hydroxide that reacted with the HCl produced by the reaction in equation 1.

amount = ... mol [1]

- (e) Calculate the amount, in moles, of HCl produced by the reaction in equation 1.

amount = ... mol [1]

(f) Calculate the amount, in moles, of XCl_4 in the original 0.17 g sample.

amount = ... mol [1]

(g) Calculate the molecular mass, M_r , of XCl_4 .

M_r = ... [1]

(h) Calculate the relative atomic mass, A_r , of **X** and suggest its identity.

A_r of **X** = ...

identity of **X**
[2]

[Total: 9]

- 2 For many compounds the enthalpy change of formation cannot be calculated directly. An indirect method based on enthalpy changes of combustion can be used.

The enthalpy change of combustion can be found by a calorimetry experiment in which the heat energy given off during combustion is used to heat a known mass of water and the temperature change recorded.

- (a) (i) Explain the meaning of the term *standard enthalpy change of combustion*.

.....

 [3]

- (ii) Write the equation for the complete combustion of ethanol, $\text{C}_2\text{H}_5\text{OH}$.

..... [1]

- (b) In an experiment to determine the enthalpy change of combustion of ethanol, 0.23 g of ethanol was burned and the heat given off raised the temperature of 100 g of water by 16.3°C .

- (i) Calculate the heat energy change, q , during the combustion of 0.23 g of ethanol.

$q = \dots\dots\dots \text{J}$ [1]

- (ii) Calculate the enthalpy change on burning 1 mole of ethanol. Include a sign in your answer.

$\Delta H = \dots\dots\dots \text{kJ mol}^{-1}$ [1]

- (iii) Suggest **two** reasons why the value for the enthalpy change of combustion of ethanol determined by a simple laboratory calorimetry experiment is likely to be lower than the true value.

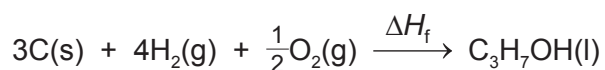
.....

 [2]

(c) The table gives some enthalpy change of combustion values.

substance	enthalpy change of combustion / kJ mol^{-1}
C(s)	-393.5
H ₂ (g)	-285.8
C ₃ H ₇ OH(l)	-2021.0

- (i) Construct a labelled energy cycle to show how these values could be used to calculate the enthalpy change of formation of C₃H₇OH(l), ΔH_f .



[3]

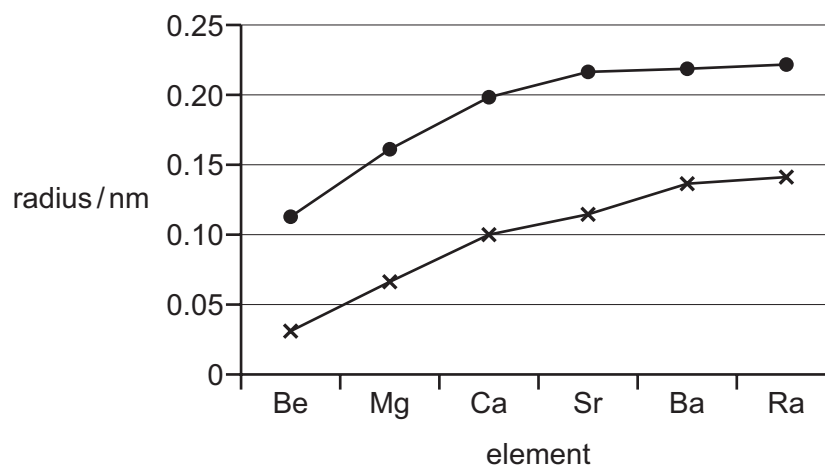
- (ii) Calculate the enthalpy change of formation, ΔH_f , of C₃H₇OH(l).

$\Delta H_f = \dots\dots\dots \text{kJ mol}^{-1}$ [2]

[Total: 13]

- 3 The elements in Group 2 and their compounds show various trends in their physical and chemical properties.

(a) The graph below shows the radius values of the atoms and 2+ ions of the elements in Group 2.



- (i) Explain why both lines show a steady increase in the values of the radii down the group.

.....

 [2]

- (ii) State and explain which line represents the atomic radii and which represents the ionic radii.

.....

 [2]

- (b) **L** is a salt of a Group 2 element **M**.

When **L** is heated strongly a brown gas is observed and a white solid remains.

The white solid dissolves in water to form a colourless solution of the metal hydroxide $\text{M}(\text{OH})_2$.

Addition of dilute sulfuric acid to this colourless solution produces a dense white precipitate.

- (i) Identify the anion in salt **L**.

..... [1]

- (ii) Identify the element **M** and write an **ionic** equation for the formation of the white precipitate with sulfuric acid.

M = ...

equation [1]

- (iii) Give the formula of salt **L** and use it to write an equation for the thermal decomposition of salt **L**.

formula of salt **L**

equation [2]

- (c) Calcium carbonate and calcium hydroxide can both be used in agriculture to neutralise acidic soils.

- (i) Write **ionic** equations for the neutralisation of acid by each of calcium hydroxide and calcium carbonate.

calcium hydroxide

calcium carbonate [2]

- (ii) Suggest and explain why calcium carbonate is a better choice than calcium hydroxide for this purpose in areas of high rainfall.

.....

.....

..... [2]

- (d) Magnesium reacts with both cold water and steam.

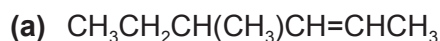
Give the formula of the magnesium-containing product of each of these reactions.

with cold water

with steam [2]

[Total: 14]

- 4 In each section of this question an organic compound is shown. For each compound give its name and answer the questions about it.



(i) name [1]

(ii) This compound shows stereoisomerism.

Define *stereoisomerism*.

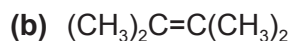
.....

 [1]

(iii) State and explain how many stereoisomers of this structure there are.

.....

 [4]



(i) name [1]

(ii) Draw the **skeletal** formula of the organic product of the reaction of this compound with cold, dilute, acidified manganate(VII) ions.

[1]

(iii) Name the organic product of the reaction of this compound with hot, concentrated, acidified manganate(VII) ions.

..... [1]

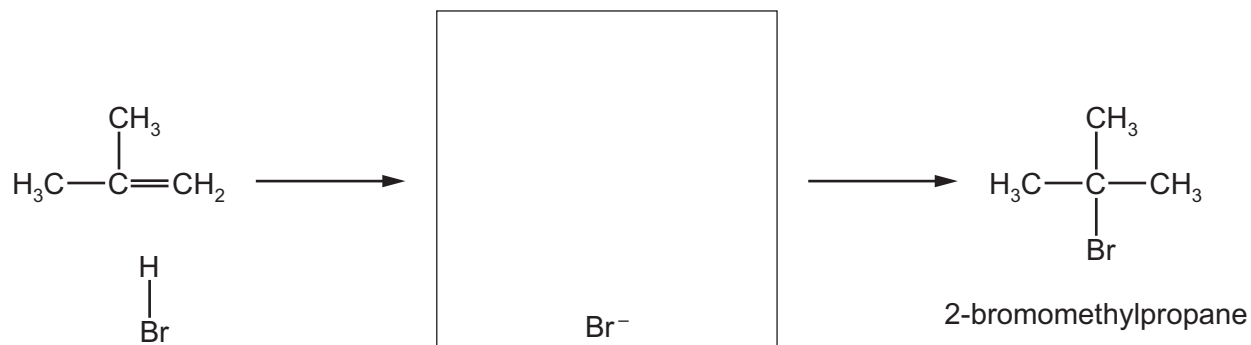
(iv) Draw the structure of part of a molecule of the addition polymer formed from this compound, showing exactly **three** repeat units.

[1]

(c) $(\text{CH}_3)_2\text{C}=\text{CH}_2$

(i) name [1]

(ii) Complete the mechanism for the reaction of this compound with hydrogen bromide. Include all necessary curly arrows, lone pairs, charges and partial charges.



[4]

(iii) Explain fully why 2-bromomethylpropane is the major product of this reaction while only relatively small amounts of 1-bromomethylpropane are produced.

.....

.....

.....

.....

.....

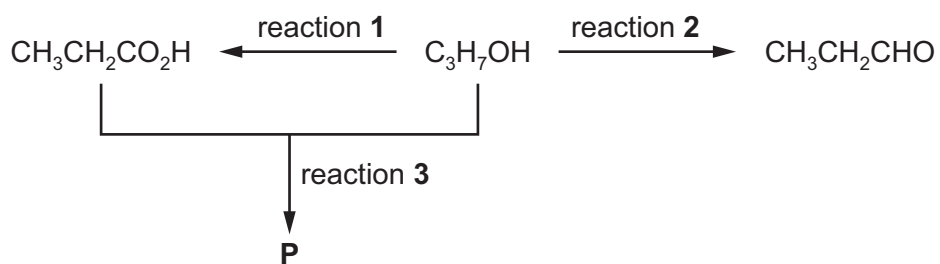
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.....

[3]

[Total: 18]

- 5 A sequence of reactions is shown starting with an alcohol, $\text{C}_3\text{H}_7\text{OH}$.



- (a) Draw the skeletal formula of the alcohol $\text{C}_3\text{H}_7\text{OH}$.

[1]

- (b) State the reagents and conditions needed for reaction 1.

.....
 [2]

- (c) State the reagents and conditions needed for reaction 2.

.....
 [2]

- (d) Name **P**, the organic product of reaction 3.

..... [1]

[Total: 6]

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9701/22

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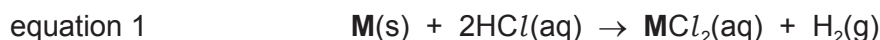
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Answer **all** the questions in the spaces provided.

- 1 A 0.50 g sample of a Group 2 metal, **M**, was added to 40.0 cm³ of 1.00 mol dm⁻³ hydrochloric acid (an excess).



- (a) Calculate the amount, in moles, of hydrochloric acid present in 40.0 cm³ of 1.00 mol dm⁻³ HCl.

amount = ... mol [1]

- (b) When the reaction had finished, the resulting solution was made up to 100 cm³ in a volumetric flask.

A 10.0 cm³ sample of the solution from the volumetric flask required 15.0 cm³ of 0.050 mol dm⁻³ sodium carbonate solution, Na₂CO₃, for complete neutralisation of the remaining hydrochloric acid.

- (i) Write the equation for the complete reaction of sodium carbonate with hydrochloric acid.

..... [1]

- (ii) Calculate the amount, in moles, of sodium carbonate needed to react with the hydrochloric acid in the 10.0 cm³ sample from the volumetric flask.

amount = ... mol [1]

- (iii) Calculate the amount, in moles, of hydrochloric acid in the 10.0 cm³ sample.

amount = ... mol [1]

- (iv) Calculate the total amount, in moles, of hydrochloric acid remaining after the reaction shown in equation 1.

amount = ... mol [1]

- (v) Use your answers to (a) and (b)(iv) to calculate the amount, in moles, of hydrochloric acid that reacted with the 0.50 g sample of **M**.

amount = ... mol [1]

- (vi) Use your answer to (v) and equation 1 to calculate the amount, in moles, of **M** in the 0.50 g sample.

amount = ... mol [1]

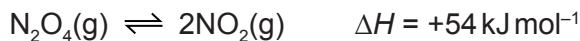
- (vii) Calculate the relative atomic mass, A_r , of **M** and identify **M**.

A_r of **M** = ...

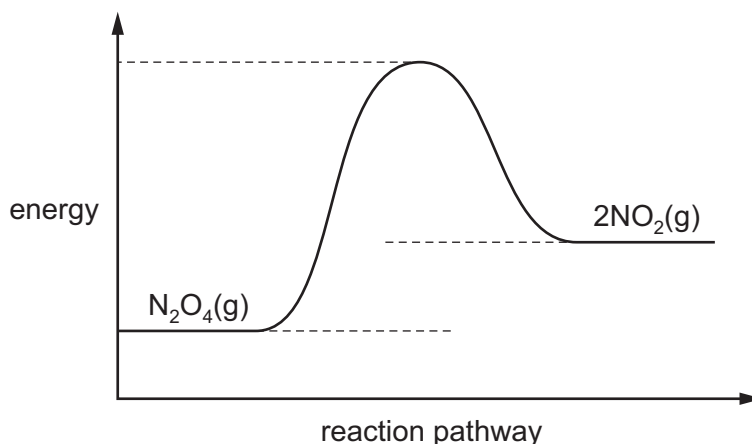
identity of **M** = ...
[2]

[Total: 9]

- 2 Dinitrogen tetroxide, N_2O_4 , and nitrogen dioxide, NO_2 , exist in dynamic equilibrium with each other.



The energy profile for this reaction is shown.



- (a) Add labelled arrows to the energy profile to indicate

- the enthalpy change of the reaction, ΔH ,
- the activation energy of the forward reaction, E_a .

[2]

- (b) 0.0500 mol of N_2O_4 was placed in a sealed vessel of volume 1.00 dm^3 , at a temperature of 50°C and a pressure of $1.68 \times 10^5 \text{ Pa}$. The mass of the resulting equilibrium mixture was 4.606 g.

- (i) Calculate the average molecular mass, M_r , of the resulting equilibrium mixture. Give your answer to **three** significant figures.

$M_r = \dots\dots\dots$ [2]

- (ii) The number of moles of N_2O_4 that dissociated can be represented by n .

State, in terms of n , the amount, in moles, of NO_2 in the equilibrium mixture.

moles of $\text{NO}_2 = \dots\dots\dots$ [1]

The number of moles of N_2O_4 remaining at equilibrium is $(0.05 - n)$.

- (iii) State, in terms of n , the total amount, in moles, of gas in the equilibrium mixture.

[1]

- (iv) State, in terms of n , the mole fraction of NO_2 in the equilibrium mixture.

[1]

In this equilibrium mixture, the mole fraction of NO_2 is 0.400.

- (v) Use your answers to (ii) and (iv) to calculate the amount in moles of each gas in the equilibrium mixture. Give your answers to **three** significant figures.

amount of N_2O_4 = ... mol

amount of NO_2 = ... mol

[2]

- (vi) Write the expression for the equilibrium constant, K_p , for this equilibrium.

$K_p =$

[1]

- (vii) Use the total pressure of the mixture, $1.68 \times 10^5 \text{ Pa}$, to calculate the value of the equilibrium constant, K_p , and give its units.

$K_p =$

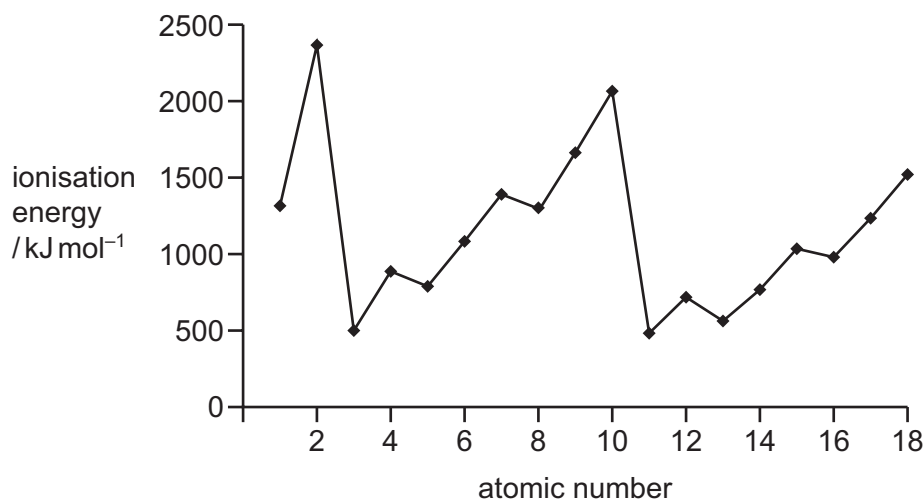
units = ...

[3]

[Total: 13]

3 The Periodic Table is arranged such that the properties of the elements show a number of trends.

(a) A plot of the first ionisation energies for the first 18 elements is shown.



(i) Explain why the values show a general increase from atomic number 11 to 18.

.....

 [2]

(ii) Explain the decreases in first ionisation energies between

- atomic numbers 12 and 13,

.....

- atomic numbers 15 and 16.

.....

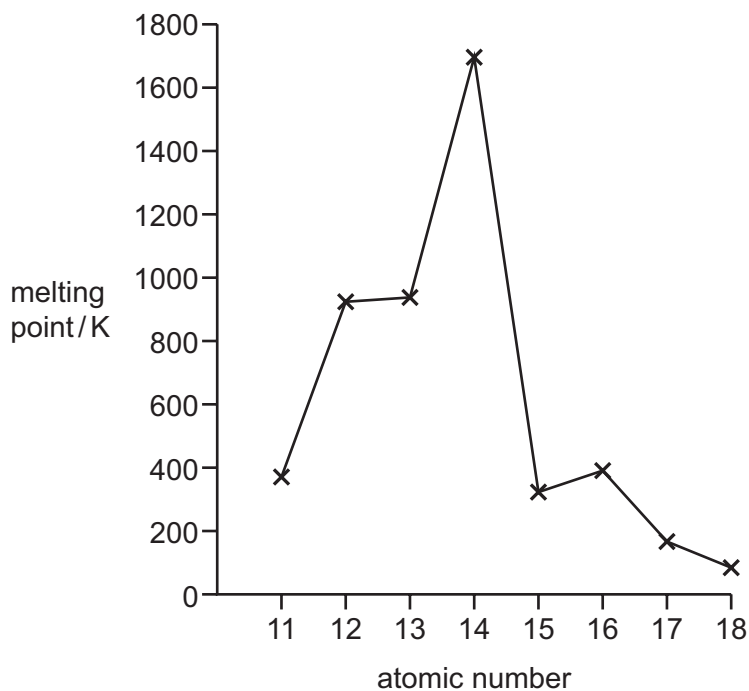
 [4]

(iii) Suggest an explanation for the trend in the first ionisation energies of the elements with atomic numbers 2, 10 and 18.

.....

 [2]

(b) A plot of the melting points of the elements across the third period is shown.



(i) Explain the increase in melting point from atomic number 11 to 12.

.....

 [2]

(ii) Suggest a reason why the increase from atomic number 12 to 13 is much smaller than the increase from atomic number 11 to 12.

.....
 [1]

(iii) State and explain the pattern of the melting points from atomic number 15 to 18.

.....

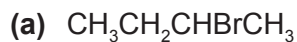
 [3]

(iv) Explain why the element with atomic number 14 has a melting point so much higher than the rest of the elements in the third period.

.....
 [1]

[Total: 15]

- 4 In each section of this question the structural formula of an organic compound is shown. For each compound answer the questions about it.



- (i) Name this compound.

..... [1]

- (ii) This compound shows stereoisomerism.

Draw the **two** stereoisomers in the conventional way.

.....

[2]

- (iii) Give the structures of **three** other structural isomers of $\text{C}_4\text{H}_9\text{Br}$.



[3]

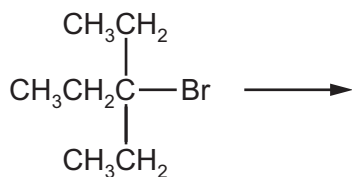


- (i) Name this compound.

..... [1]

- (ii) $(\text{C}_2\text{H}_5)_3\text{CBr}$ reacts with aqueous OH^- .

Complete the mechanism for this reaction including all necessary curly arrows, charges, partial charges and lone pairs.



[3]

- (iii) What *type of mechanism* occurs in (ii)?

..... [1]

(c) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHBrCH}_3$

- (i) Give the reagents and conditions necessary for the conversion of this compound into a mixture of alkenes.

.....
..... [2]

- (ii) Give the name of the mechanism for the conversion in (i).

..... [1]

- (iii) Draw the skeletal formulae of the three alkenes produced by the conversion in (i).



[3]

[Total: 17]

5 In each section of this question choose the answer or answers from the options listed.

(a) Six particles are listed.



(i) Identify **two** particles produced during the reaction of methane and chlorine in the presence of UV light.

..... [1]

(ii) Identify the **two** particles produced by the heterolytic fission of a bond in chloromethane.

..... [1]

(b) Seven reaction types are listed.

addition substitution oxidation elimination

hydrolysis condensation reduction

(i) Name the type of reaction involved when Tollens' reagent is used to identify an aldehyde.

..... [1]

(ii) Name the type of reaction involved in the test for a carbonyl group using 2,4-DNPH.

..... [1]

(iii) Name the type of reaction involved in the reaction of a ketone with NaBH_4 .

..... [1]

(iv) Name the type of reaction involved in the reaction of an aldehyde with HCN.

..... [1]

[Total: 6]

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CHEMISTRY

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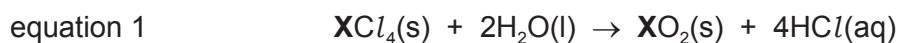
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- (a) Calculate the amount, in moles, of hydrochloric acid used in the titration to neutralise the unreacted sodium hydroxide solution.

amount = ... mol [1]

- (b) Write the equation for the reaction between hydrochloric acid and sodium hydroxide.

..... [1]

- (c) Calculate the amount, in moles, of sodium hydroxide neutralised in the titration.

amount = ... mol [1]

- (d) Calculate the amount, in moles, of sodium hydroxide that reacted with the HCl produced by the reaction in equation 1.

amount = ... mol [1]

- (e) Calculate the amount, in moles, of HCl produced by the reaction in equation 1.

amount = ... mol [1]

(f) Calculate the amount, in moles, of XCl_4 in the original 0.17 g sample.

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(g) Calculate the molecular mass, M_r , of XCl_4 .

M_r = ... [1]

(h) Calculate the relative atomic mass, A_r , of X and suggest its identity.

A_r of X = ...

identity of X
[2]

[Total: 9]

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..... [1]

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- (ii) Calculate the enthalpy change on burning 1 mole of ethanol. Include a sign in your answer.

$\Delta H = \dots\dots\dots \text{kJ mol}^{-1}$ [1]

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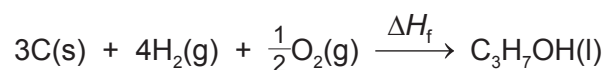
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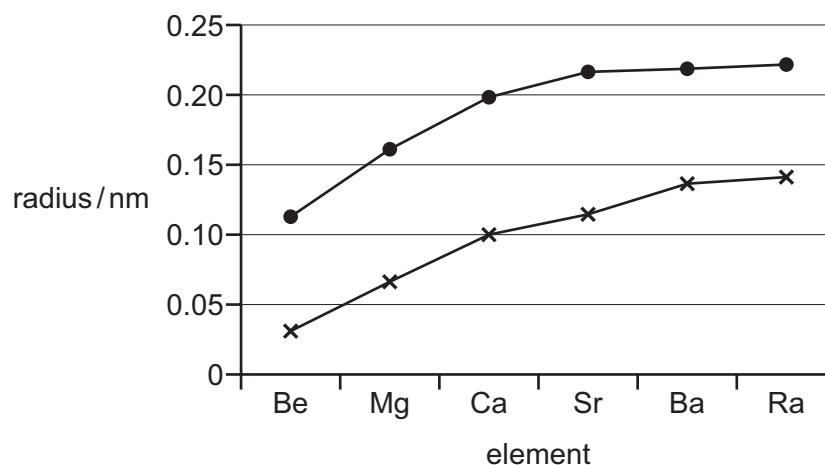
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- (ii) State and explain which line represents the atomic radii and which represents the ionic radii.

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Addition of dilute sulfuric acid to this colourless solution produces a dense white precipitate.

- (i) Identify the anion in salt **L**.

..... [1]

- (ii) Identify the element **M** and write an **ionic** equation for the formation of the white precipitate with sulfuric acid.

M = ...

equation [1]

- (iii) Give the formula of salt **L** and use it to write an equation for the thermal decomposition of salt **L**.

formula of salt **L**

equation [2]

- (c) Calcium carbonate and calcium hydroxide can both be used in agriculture to neutralise acidic soils.

- (i) Write **ionic** equations for the neutralisation of acid by each of calcium hydroxide and calcium carbonate.

calcium hydroxide

calcium carbonate [2]

- (ii) Suggest and explain why calcium carbonate is a better choice than calcium hydroxide for this purpose in areas of high rainfall.

.....

.....

..... [2]

- (d) Magnesium reacts with both cold water and steam.

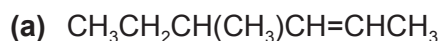
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with cold water

with steam [2]

[Total: 14]

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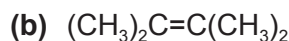
.....

 [1]

(iii) State and explain how many stereoisomers of this structure there are.

.....

 [4]



(i) name [1]

(ii) Draw the **skeletal** formula of the organic product of the reaction of this compound with cold, dilute, acidified manganate(VII) ions.

[1]

(iii) Name the organic product of the reaction of this compound with hot, concentrated, acidified manganate(VII) ions.

..... [1]

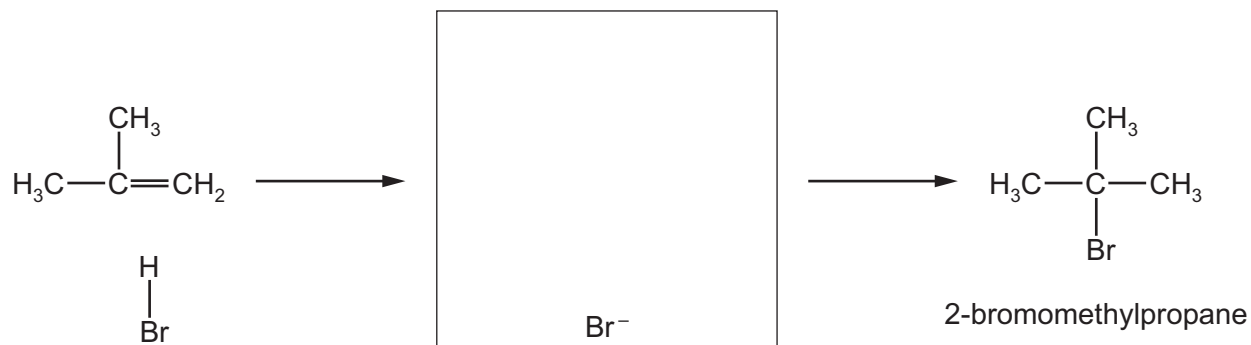
(iv) Draw the structure of part of a molecule of the addition polymer formed from this compound, showing exactly **three** repeat units.

[1]

(c) $(\text{CH}_3)_2\text{C}=\text{CH}_2$

(i) name [1]

(ii) Complete the mechanism for the reaction of this compound with hydrogen bromide. Include all necessary curly arrows, lone pairs, charges and partial charges.



[4]

(iii) Explain fully why 2-bromomethylpropane is the major product of this reaction while only relatively small amounts of 1-bromomethylpropane are produced.

.....

.....

.....

.....

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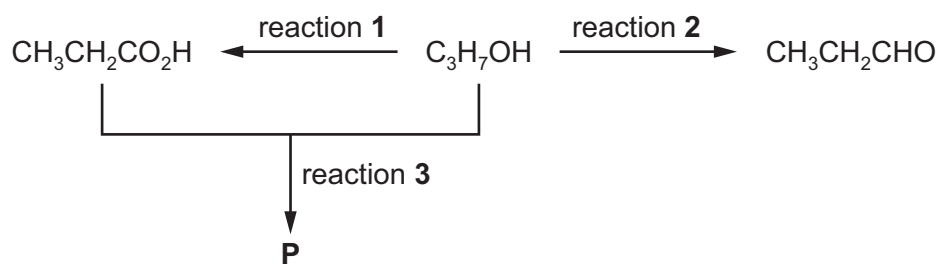
.....

.....

[3]

[Total: 18]

- 5 A sequence of reactions is shown starting with an alcohol, $\text{C}_3\text{H}_7\text{OH}$.



- (a) Draw the skeletal formula of the alcohol $\text{C}_3\text{H}_7\text{OH}$.

[1]

- (b) State the reagents and conditions needed for reaction 1.

.....
 [2]

- (c) State the reagents and conditions needed for reaction 2.

.....
 [2]

- (d) Name **P**, the organic product of reaction 3.

..... [1]

[Total: 6]

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