Class Adm. No.

Candidate Name: _____

H

millennia institute

2025 Preliminary Examination
Pre-University 2

H1 CHEMISTRY **8873/02**

Paper 2 Structured Questions **27 August 2025**

2 hours

Candidates answer on the Question paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so.

Write your name, class and admission number in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [ ] at the end of each question or part question.

Question	Section A				Section B	**Total**
	1	2	3	4	5 / 6	
Marks	/19	/11	/22	/8	/20	**/80**

Section A

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

1 **(a)** Graphene is a nanomaterial.

(i) Draw a diagram to represent part of a graphene layer which contains at least five complete rings of carbon atoms.

[1]

(ii) Graphene has high tensile strength. Explain what this means.

.....

.....[1]

(iii) Explain why graphene has high tensile strength.

.....

.....[1]

(iv) Graphene is able to conduct electricity. Explain why.

.....

.....

.....[1]

(b) Nickel catalyses a reaction between methane and steam.

(i) State the electronic configuration of Ni.

$1s^2$ .....[1]

(ii) Outline the mode of action as nickel catalyses the reaction between methane and steam.

Include bond forming and bond breaking in your answer.

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.....[3]

(iii) The nickel catalyst is made of nanoparticles. Explain what it means by a *nanoparticle*.

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.....[1]

(iv) Explain how nickel being made of nanoparticles would facilitate the catalysis of the reaction.

.....

.....[1]

(c) Methane and steam react to form a mixture of carbon monoxide and hydrogen known as syngas.

All four gases exist as an equilibrium mixture.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H$$

(i) In the carbon monoxide molecule, one of the covalent bonds is a dative bond.

Draw the 'dot-and-cross' diagram to show the bonding in a molecule of carbon monoxide.

[1]

(ii) Use bond energy values from the *Data Booklet* to calculate the enthalpy change of the forward reaction, ΔH.

[2]

(iii) In the manufacture of syngas, 1.00 mol of $CH_4(g)$ and 1.00 mol of $H_2O(g)$ were injected into a 2.00 dm^3 reaction chamber at 700 °C.

At equilibrium, 0.26 mol of CO(g) was formed.

Calculate the equilibrium constant, K_c, for the reaction at 700 °C.

[2]

(iv) With reference to your answer in **(c)(ii)**, explain how increasing the temperature to 1000 °C would affect the equilibrium position and K_c value.

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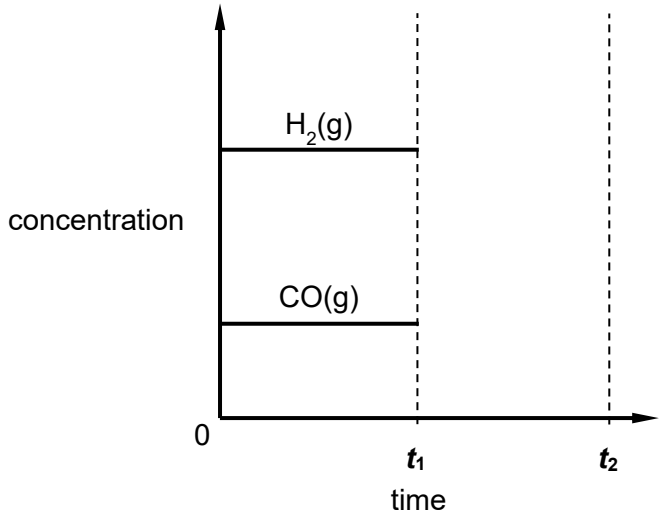
.....[2]

(v) At time t_1, the reaction chamber was suddenly compressed such that its volume decreased.

Complete the graph below until time t_2 to show how the concentrations of CO(g) and H_2(g) would change as a result of the sudden compression.



[2]

[Total: 19]

2 **(a)** Hydrogen halides are molecules consisting of a hydrogen atom covalently bonded to a halogen atom.

	HF	HC*l*	HBr	HI
boiling point / °C	20	–85	–66	–35

(i) Explain the relative boiling points of the 4 hydrogen halides shown above.

.....

.....

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.....

.....[3]

(ii) State and explain the trend in thermal stability of the 4 hydrogen halides shown above.

.....

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.....

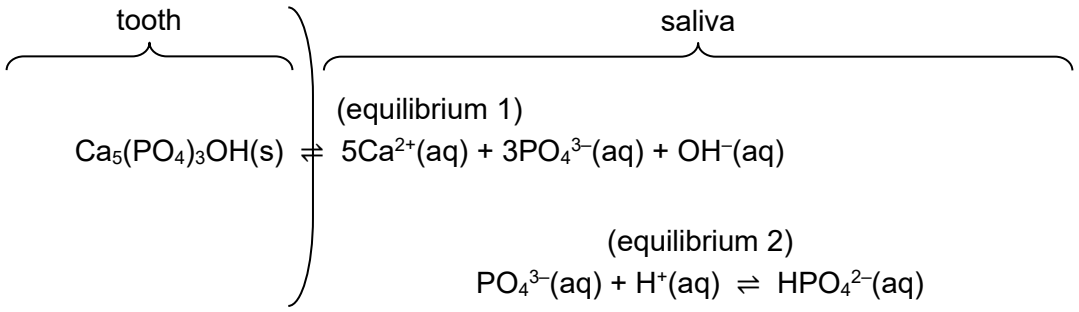
.....

.....[2]

(b) Healthy teeth are protected by a hard layer of enamel. The main component of enamel is hydroxyapatite, $Ca_5(PO_4)_3OH$.

Hydroxyapatite exists in equilibrium with its aqueous ions (equilibrium 1) in the saliva, which is the surrounding fluid.

The saliva itself consists of various ions, making it a buffer solution (equilibrium 2).



(i) Explain, in terms of structure and bonding, why hydroxyapatite is hard.

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.....[2]

(ii) Explain, by reference to equilibrium 2, how saliva behaves as a buffer solution.

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.....[2]

(iii) Bacteria present in the mouth break down food residues on the teeth surface, producing acids. Consuming sodas would also increase acid content in the mouth.

Using equilibria 1 and 2, explain how a high acid content would eventually corrode enamel and result in tooth decay.

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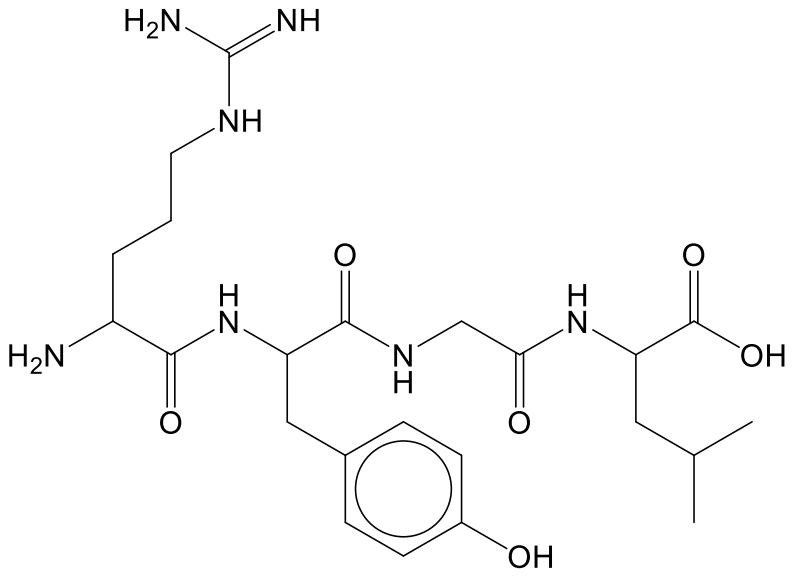
.....[2]

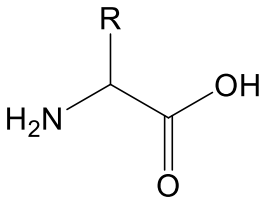
[Total: 11]

3 **(a)** Milk contains casein molecules.



casein

A casein molecule is a polyamide, and is made of amino acid molecules joined together to form numerous amide bonds, –CONH–.



amino acid molecule
where R represents a side group

(i) State the type of reaction when amino acids react to form a casein molecule.

.....[1]

(ii) The bonds holding the amino acid molecules together in casein can be broken by hydrolysis.

Suggest the reagent and condition required to hydrolyse casein and release the separate amino acid molecules.

.....[1]

(iii) Draw the structure of the amino acid molecule from the hydrolysis of casein that has the lowest M_r.

[1]

(iv) Draw the structure of the amino acid molecule from the hydrolysis of casein that can form the most hydrogen bonds with water per molecule.

[1]

(b) Milk turns sour and expires after some time. This process is a chemical reaction.

Table 3.1 shows the time taken for milk to expire when stored at various temperatures.

Table 3.1

temperature / °C	15	10	7	4	0
number of days	1	2	5	10	24

Using appropriate Boltzmann distribution curves, explain the trend shown in Table 3.1.

.....

.....

.....

.....[3]

(c) Milk turns sour over time due to bacteria present fermenting milk sugars to form acids. These bacteria would also multiply, causing the milk to become unsafe for consumption.

The acids also cause the casein molecules to curdle and clump together.

In some parts of the world, milk is adulterated by unscrupulous producers by adding various substances. This is done to increase their own profit margins, extend the shelf life of the milk, or to make expired milk appear fresh.

One possible adulterant is water, which dilutes the milk. Other possible adulterants are hydrogen peroxide, sodium carbonate, and starch.

A department in a food safety agency is responsible for detecting adulterants in milk. Aqueous potassium iodide is used to detect the presence of hydrogen peroxide, while aqueous iodine is used to detect starch.

The results of the testing for five samples of milk are shown in Table 3.2.

Table 3.2

sample	test with KI(aq)	test with I_2(aq)	pH	density / g cm^{-3}
1	no gas formed	dark blue colour obtained	6.9	1.105
2	no gas formed	no colour change	4.2	1.346
3	no gas formed	no colour change	6.4	1.032
4	effervescence of colourless gas formed	no colour change	6.5	1.029
5	no gas formed	no colour change	7.0	1.001

(i) Write a balanced chemical equation for the decomposition of hydrogen peroxide to form a gas.

.....[1]

(ii) Suggest one possible reason for adding each of the following adulterants into milk.

hydrogen peroxide .....

.....

starch .....

.....
[2]

(iii) Sodium carbonate is basic and would increase the pH of milk.

Write an ionic equation to show how sodium carbonate behaves as a base.

.....[1]

(iv) Sample 3 was found to be safe for consumption.

Samples 1, 4 and 5 were found to contain adulterants.

State what the results in Table 3.2 show about the adulterants found in the milk samples 1, 4 and 5.

sample 1 .....

.....

sample 4 .....

.....

sample 5 .....

.....
[3]

(v) Although sample 2 was not found to have any adulterants, it was still deemed unsafe for consumption.

Using Table 3.2, explain what could have happened to the milk.

.....

.....

.....

.....[2]

(d) The acid formed from fermentation, RCO_2H, was isolated, purified, and dried.

11.1 g of RCO_2H was added into a volumetric flask and dissolved in water to form 250 cm^3 of solution.

To the solution of RCO_2H(aq), 25.0 cm^3 was pipetted out and titrated with 0.500 mol dm^{-3} aqueous sodium hydroxide.

24.65 cm^3 of sodium hydroxide was required to reach end-point.

(i) Suggest a suitable indicator for this titration. Explain your answer.

.....

.....

.....

.....[2]

(ii) Calculate the relative molecular mass of RCO_2H.

[2]

(iii) When RCO_2H was heated with acidified potassium manganate(VII), the purple solution turned colourless, and RCO_2H was converted into **K**.

K could be reduced by alcoholic sodium borohydride to reform RCO_2H.

Using this information and the relative molecular mass you have calculated in **(d)(ii)**, deduce the structures of RCO_2H and **K**.

RCO_2H	**K**

[2]

[Total: 22]

4 **(a)** **(i)** State and explain the trend in first ionisation energy of the elements down Group 1 of the Periodic Table.

.....

.....

.....

.....[2]

(ii) Sodium is a Group 1 metal that can undergo a combustion reaction with oxygen.

Write a balanced chemical equation for the reaction between sodium and oxygen.

.....[1]

(iii) State the role of sodium in its reaction with oxygen in **(a)(ii)** and explain your answer.

.....

.....

.....[2]

(iv) Lithium is another Group 1 metal. It can also undergo a combustion reaction with oxygen.

State how the rate of reaction between lithium and oxygen will differ from the rate of reaction between sodium and oxygen. Explain your answer.

.....

.....

.....[1]

(b) Alcohols can be combusted in oxygen.

An alcohol, C_xH_yO, was vapourised and 10 cm^3 of it reacted with 60 cm^3 oxygen to form 40 cm^3 carbon dioxide. All volumes were measured at the same temperature and pressure.

Write a balanced chemical equation for the combustion of C_xH_yO, and hence state the molecular formula of C_xH_yO.

chemical equation .....

molecular formula of alcohol .....
[2]

[Total: 8]

Section B

Answer **one** question from this section in the spaces provided.

5 **(a)** Tritium, ^{3}H, is an isotope of hydrogen.

(i) Define *isotopes*.

.....

.....[1]

(ii) State the number of protons, neutrons and electrons in an atom of tritium, ^{3}H.

protons	neutrons	electrons

[1]

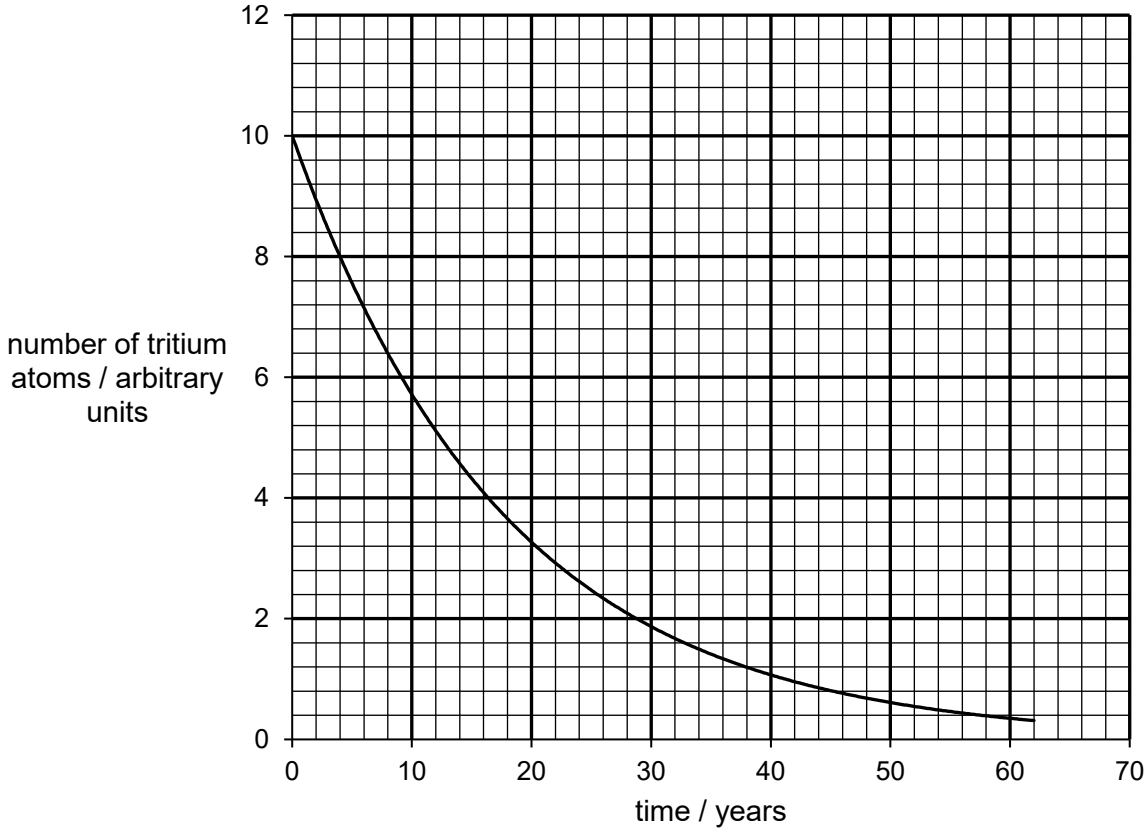
(iii) Tritium is radioactive and undergoes beta-decay.

During the process, one neutron is converted into one proton and one electron.

Write the nuclide notation for the resultant atom in the form $^{A}_{Z}X$.

.....[1]

(b) The radioactive decay of a sample of tritium was followed over time.



(i) Explain what is meant by the term half-life of a reaction.

.....

.....[1]

(ii) Use the graph to determine the half-life of this reaction.

Show your working on the graph.

.....

.....[1]

(iii) Deduce the order with respect to tritium.

Explain how you arrived at your answer.

.....

.....[2]

(iv) Another sample of tritium contains two times the number of atoms.

State how the half-life of this sample of tritium will differ from that calculated in **(b)(ii)**.

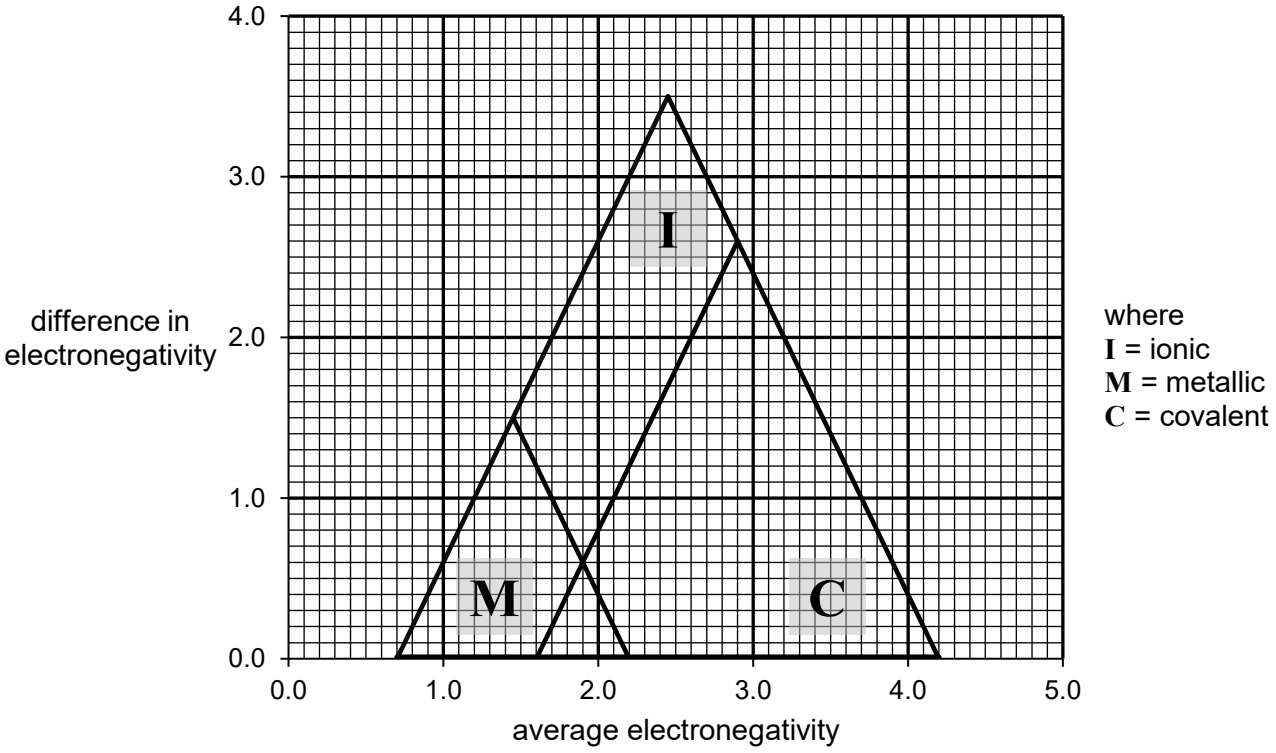
.....

.....[1]

(c) The van Arkel triangle is used to predict the type of bonding between two elements in a compound.

The type of bonding depends on the average electronegativity of the two elements, and the electronegativity difference between the two elements.

The average electronegativity and difference in electronegativity are not affected by the number of atoms present in the compound.



(i) The electronegativity values of some elements are shown.

chlorine	fluorine	phosphorus
3.2	4.0	2.2

On the van Arkel diagram above, place **<u>two</u>** crosses ×, one for phosphorus trichloride, PCl_3, and one for phosphorus trifluoride, PF_3.

Label your two crosses clearly with the compounds they represent. [2]

(ii) The P–F bond is more polar than the P–C*l* bond.

State how your answer in **(c)(i)** shows this.

.....[1]

(iii) On the van Arkel diagram above, place a **<u>third</u>** cross × for oxygen gas, O_2.

Label your cross clearly with 'O_2'. [1]

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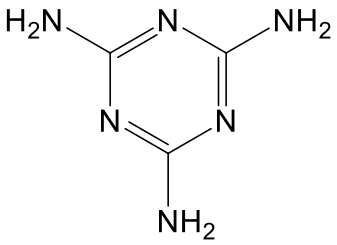
(d) Melamine is used to manufacture dinnerware.



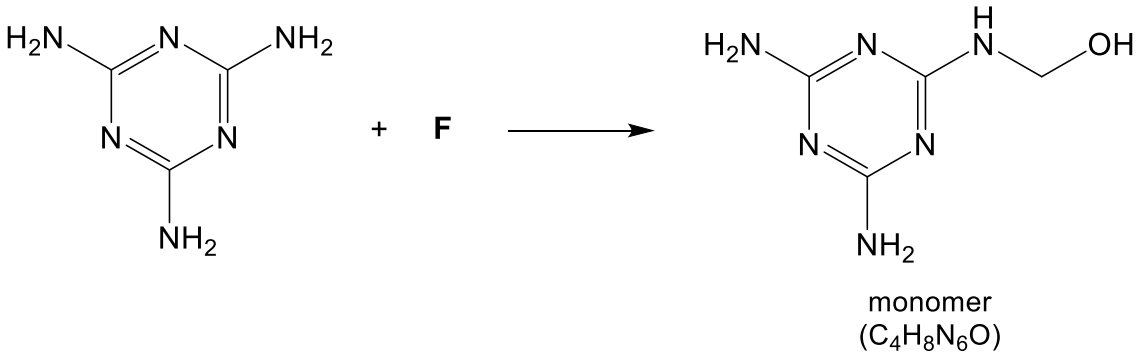
melamine

(i) State the number of σ bonds and π bonds in one molecule of melamine.

.....

.....[1]

(ii) Melamine, $C_3H_6N_6$, is combined with a small molecule **F** to form a monomer, $C_4H_8N_6O$.

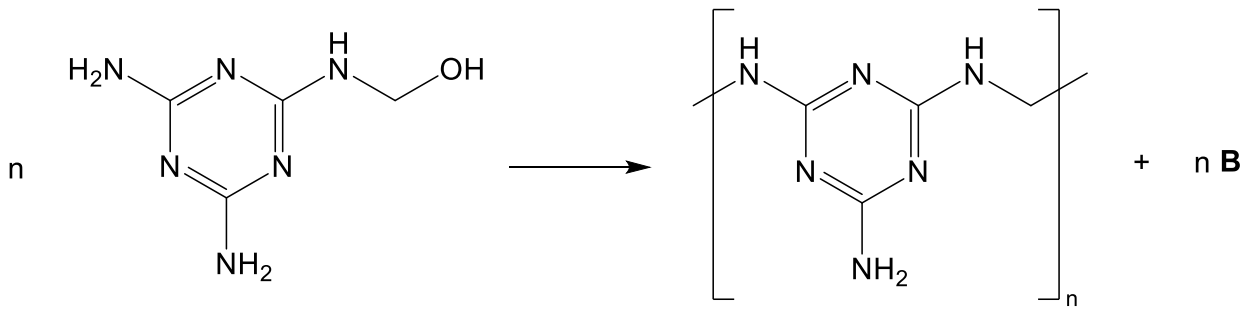


monomer
($C_4H_8N_6O$)

Using the formulas of melamine and the monomer, deduce the structure of **F**.

[1]

(iii) The monomers are polymerised to form melamine resin.

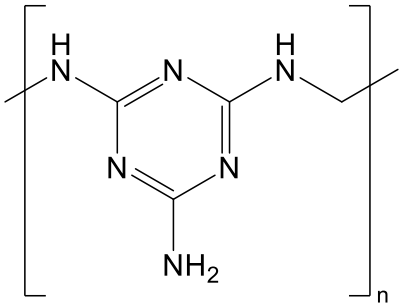


melamine resin

Molecules of **B** are eliminated as a byproduct. Identify **B**.

.....[1]

(iv) Each melamine resin polymer chain has an average relative molecular mass of 1800.



melamine resin

Calculate the average number of repeating units of melamine resin that is present in one polymer chain. Leave your answer to 3 significant figures.

[2]

(v) Melamine resin is a thermoset polymer.

With reference to the structure of melamine resin, explain how it becomes a thermoset polymer during the polymerisation process.

.....

.....

.....[1]

(vi) Melamine resin is used to make Melmac, a brand of dinnerware and kitchenware.

Describe one advantage and one disadvantage of using melamine resin in dinnerware.

advantage .....

.....

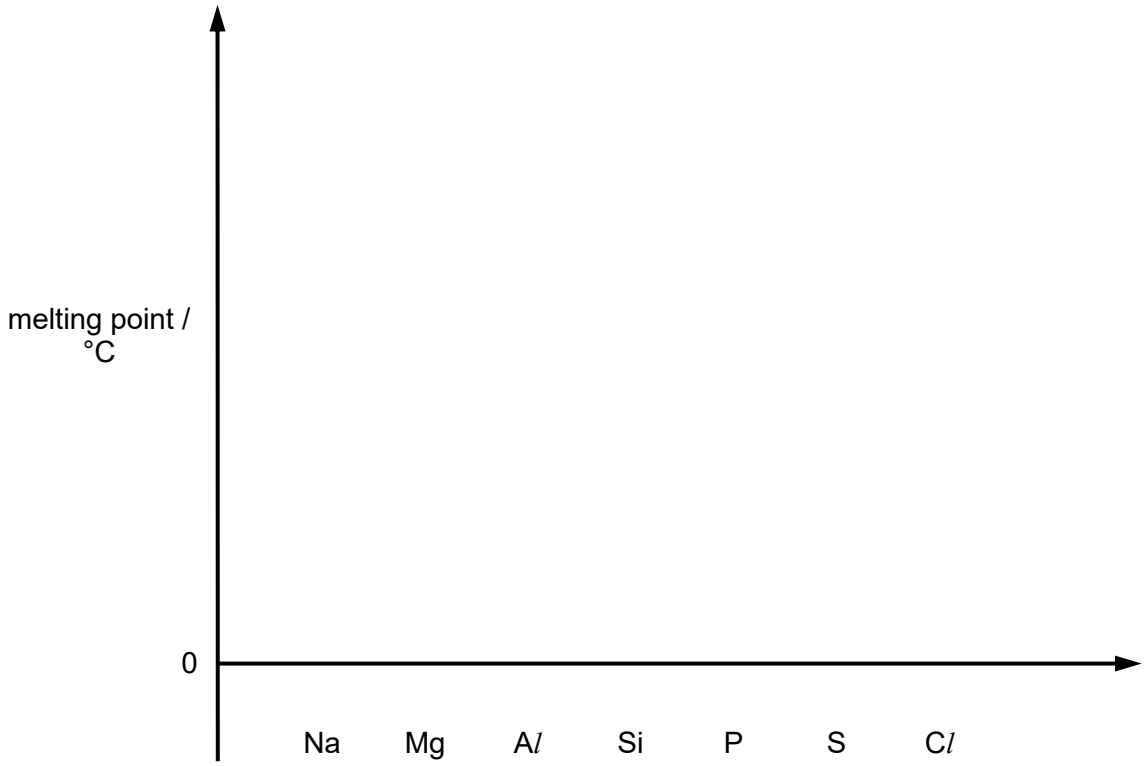
disadvantage .....

.....

[2]

[Total: 20]

6 **(a)** **(i)** On the axes below, sketch a graph showing the relative melting points of the period 3 elements.



[2]

(ii) Describe what happens when $MgCl_2$ and PCl_5 are each added separately to water.

State the pH of the resultant solutions.

Include equations for any reactions that occur.

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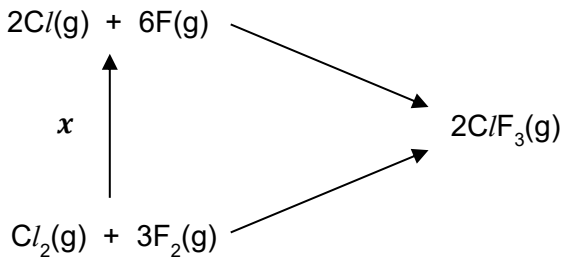
.....[4]

(b) An energy cycle is shown.



(i) Use bond energy values from the *Data Booklet* to calculate the value of x.

[1]

(ii) The standard enthalpy change of formation of C*l*F$_3$(g) is –163 kJ mol^{-1}.

Calculate the average bond energy of the C*l*–F bond in C*l*F$_3$.

[2]

(iii) State the number of electron bond pairs and electron lone pairs around the chlorine atom of the chlorine trifluoride, C*l*F$_3$, molecule.

Hence, name the shape of the chlorine trifluoride molecule based on the Valence Shell Electron Pair Repulsion Theory.

.....

.....[2]

(c) Two different methods were used to determine the percentage purity of a sample of aluminium metal.

0.175 g of the metal sample was added to 100 cm^3 of hydrochloric acid. The acid was added in excess.

$$2Al(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$$

In method **1**, the hydrogen gas produced was collected and its volume measured.

In method **2**, the maximum temperature increase of the solution was measured.

(i) In method **1**, 213 cm^3 of hydrogen gas was collected.

The volume of hydrogen gas was measured at r.t.p.

Calculate the percentage by mass of aluminium in the metal sample.

[2]

(ii) In method **2**, the maximum temperature increase was 6.7 °C.

For every 1 mol of aluminium reacted, the enthalpy change was –525 kJ.
The specific heat capacity of the solution was 4.18 J g^{-1} K^{-1}.

Calculate the percentage by mass of aluminium in the metal sample.

[2]

(iii) Suggest a reason why the results of percentage purity of aluminium calculated from method **1** and method **2** are different.

.....

.....[1]

(d) The standard enthalpy change of neutralisation, ΔH_n^θ, would be different for different acids being used to react with sodium hydroxide.

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l) \qquad \Delta H_n^\theta = -57.3 \text{ kJ mol}^{-1}$$

$$CH_3CO_2H(aq) + NaOH(aq) \longrightarrow CH_3CO_2Na(aq) + H_2O(l) \qquad \Delta H_n^\theta = -55.2 \text{ kJ mol}^{-1}$$

(i) Define *standard enthalpy change of neutralisation*.

.....

.....[1]

(ii) Explain why the reaction of ethanoic acid, CH_3CO_2H, with sodium hydroxide will give a different ΔH_n^θ from the reaction using hydrochloric acid, HCl.

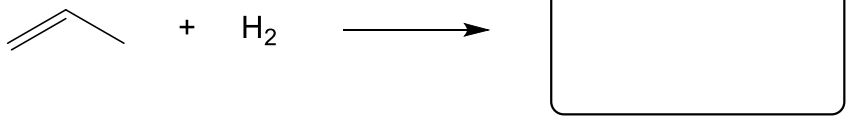
.....

.....[1]

(e) Hydrogen and chlorine can react with alkenes to form new compounds.

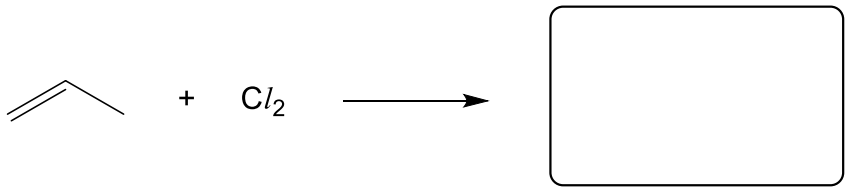
Draw the structures of the products formed from the following reactions.

(i)



[1]

(ii)



[1]

[Total: 20]

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