Class Adm No

Candidate Name: _____

H

millennia institute

2021 End-of-Year Examination
Pre-University 1

H2 CHEMISTRY **9729/01**

Paper 1 Multiple Choice & Structured Questions **15 Oct 2021**

2 hours

Additional materials: Multiple Choice Answer Sheet
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 on all the work you hand in.

For **Section A**, there are **fifteen** questions. Answer **ALL** questions. For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet provided. Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Read the instructions on the Multiple Choice Answer Sheet very carefully.

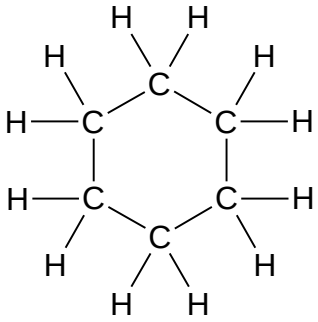
For **Section B**, write in dark blue or black pen. You may use an HB pencil for any diagrams or graphs. Do not use staples, paper clips, glue or correction fluid. Answer **all** the questions. The use of an approved scientific calculator is expected, where appropriate. Any rough working should be done in this question paper.

Question	Section A	1	2	3	4	5	6	7	**Total**
Marks	/15	/6	/9	/16	/6	/6	/3	/9	**/70**

Section A – Multiple Choice

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 Which statements about cyclohexane are correct?



cyclohexane

1 Its empirical formula is CH_2.

2 Its molecular formula is C_6H_{12}.

3 Its relative molecular mass is 48.0.

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

2 Some hydrocarbon gas was combusted in excess oxygen at room temperature and pressure.

volume of hydrocarbon gas combusted	10 cm^3
volume of oxygen available before combustion	90 cm^3
total volume of gases after combustion	70 cm^3
remaining volume of gas after passing gases through NaOH(aq)	40 cm^3

What is the molecular formula of the hydrocarbon?

A C_3H_6 **B** C_3H_8 **C** C_4H_8 **D** C_4H_{10}

3 Which statement about beryllium chloride, $BeCl_2$, is correct?

A $BeCl_2$ has a bent shape.

B $BeCl_2$ is an ionic compound.

C $BeCl_2$ can behave as a Lewis acid.

D $BeCl_2$ accepts electrons into the 1s orbital of the Be atom.

4 When zinc nitrate is heated strongly, it decomposes to form zinc oxide and two gases.

$$2Zn(NO_3)_2(s) \longrightarrow 2ZnO(s) + 4NO_2(g) + O_2(g)$$

Which statement about the decomposition of zinc nitrate is correct?

A Zinc nitrate was neither oxidised nor reduced.

B Zinc nitrate was oxidised to form zinc oxide.

C Zinc nitrate was oxidised to form nitrogen dioxide.

D Zinc nitrate was oxidised to form oxygen.

5 In an experiment, UV rays were shone on some chlorine atoms.

The chlorine atoms that absorbed a UV ray were found to have the electronic configuration $1s^2\ 2s^2\ 2p^6\ 3s^1\ 3p^6$.

What was the change in the chlorine atom due to the absorption of the UV ray?

A An electron was demoted from the 4s to 3p subshell.

B An electron was gained by the atom to the 3p subshell.

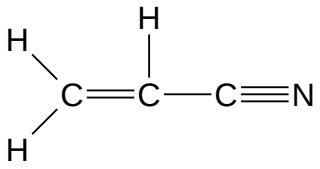
C An electron was lost by the atom from the 3s subshell.

D An electron was promoted from the 3s to 3p subshell.

6 Which atom has the highest number of half-filled orbitals?

A C **B** F **C** Mg **D** A*l*

7 How many sigma (σ) and pi (π) bonds are present in one molecule of acrylonitrile?



acrylonitrile

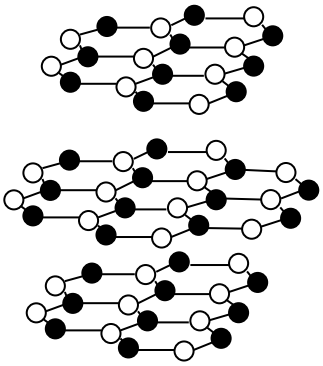
	σ bonds	π bonds
A	4	3
B	4	5
C	6	3
D	6	5

8 Which ionic compound has the highest melting point?

A CaF_2 **B** CaO **C** K_2O **D** KF

9 Hexagonal boron nitride consists of boron and nitrogen atoms forming covalent bonds with one another in an extensive hexagonal network.

All boron and nitrogen atoms in the network use up all of their available valence electrons to form covalent bonds.



● boron atom

○ nitrogen atom

Which statement is a correct property of hexagonal boron nitride?

A It is a good conductor of electricity.

B It is ductile and malleable.

C It is hard.

D It has a high melting point.

10 Which substance is ductile and malleable?

	melting point / °C	electrical conductivity in different states (s)	(*l*)	(aq)
A	122	×	×	✓
B	181	✓	✓	insoluble
C	373	×	✓	insoluble
D	802	×	✓	✓

11 Which statement correctly describes an ideal gas assumption?

A Molecules occupy an insignificant volume in the container.

B A gas is most ideal under high pressure and low temperature conditions.

C Kinetic energy is completely converted to heat energy after molecules collide.

D Only instantaneous dipole-induced dipole forces of attraction exist between molecules.

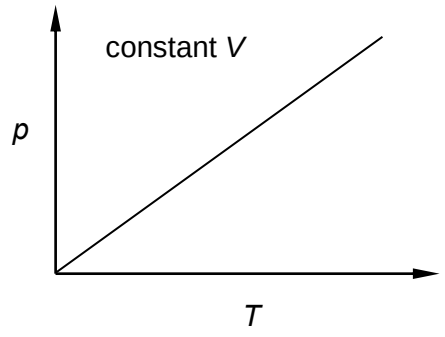
12 A gas canister holds 3.00 dm^3 of propane at 300 kPa and 0 °C.

What is the volume of the propane when it is released at standard temperature and pressure?

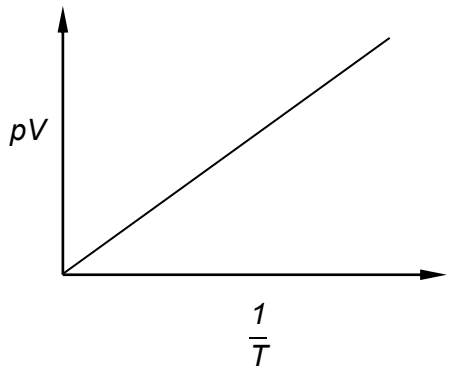
A 1.01 dm^3 **B** 8.88 dm^3 **C** 9.00 dm^3 **D** 9.82 dm^3

13 Which graph correctly shows the relationship between variables for a sample of a fixed mass of an ideal gas?

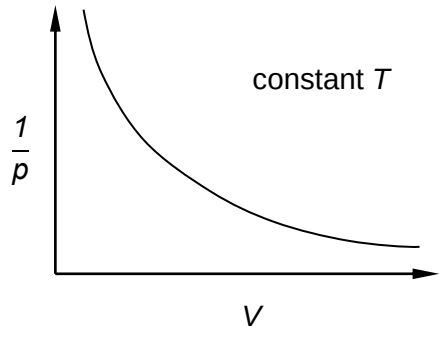
A



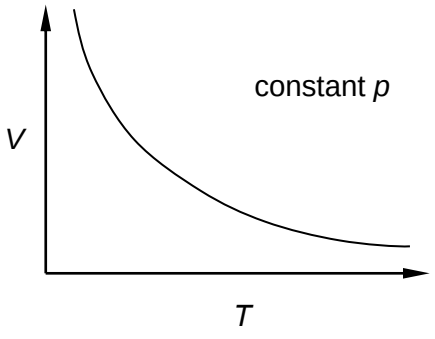
B



C



D

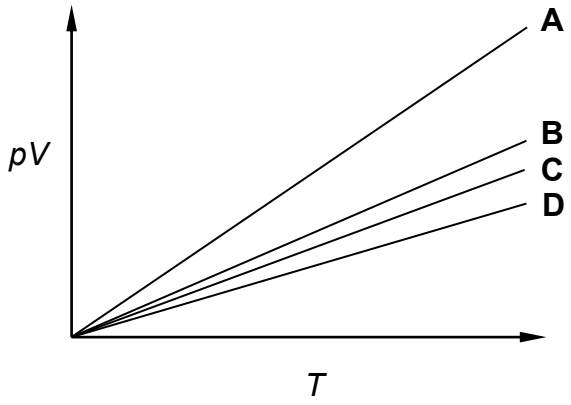


14 Experiments were performed on four gases that can be found in the atmosphere – N_2, O_2, Ar, and CH_4.

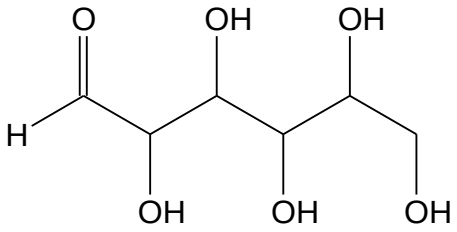
The volumes and pressures of equal masses of each gas were measured over a range of temperatures.

The results are plotted on a graph of *pV* against *T* (in units of K). All the gases are assumed to be behaving ideally.

Which graph shows the results for O_2?



15 How many enantiomers (optical isomers) of D-glucose are present?



D-glucose

A 4 **B** 8 **C** 16 **D** 32

END OF SECTION A

Section B – Structured Questions

Answer all questions.

1 Two redox reactions were used to determine the unknown concentration of a solution.

In the first reaction, acidified potassium manganate(VII) reacts with potassium iodide to liberate iodine.

(a) Write two balanced ion-electron equations for the first reaction.

.....

..... [2]

In the second reaction, the iodine that was liberated reacts with sodium thiosulfate ($Na_2S_2O_3$), forming sodium tetrathionate ($Na_2S_4O_6$).

(b) Write the overall ionic equation for the second reaction.

..... [1]

10.0 cm^3 of aqueous acidified potassium manganate(VII) was pipetted into a conical flask.

Excess aqueous potassium iodide was then added into the conical flask and the solution turned orange.

The orange mixture was titrated with 1.50 mol dm^{-3} aqueous sodium thiosulfate.

24.90 cm^3 of aqueous sodium thiosulfate was required to reach end-point.

(c) Calculate the number of moles of iodine liberated from the first reaction.

[1]

(d) Calculate the number of moles of manganate(VII) ions reacted.

[1]

(e) Calculate the concentration (in mol dm^{-3}) of aqueous potassium manganate(VII) used.

[1]

[Total: 6]

2 Nitrogen is the most abundant gas in the atmosphere.

In the upper atmosphere, a high intensity of cosmic rays can be found.

These cosmic rays constantly split apart some nitrogen molecules, forming nitrogen atoms.

$$N{\equiv}N \longrightarrow 2N$$

(a) Explain whether this reaction is exothermic or endothermic.

.....

..... [1]

(b) **(i)** Complete the electron-in-box diagram below to represent the electronic configuration of a nitrogen atom.

1s

[1]

(ii) Draw all the orbitals present in the valence electron shell of a nitrogen atom.
Show all axes, shapes, and label the orbitals clearly.

[2]

(c) These nitrogen atoms can undergo a nuclear reaction known as the 'n-p' reaction in the upper atmosphere to form atom $^{m}_{n}\mathbf{X}$.

$$^{14}N + \text{neutron} \longrightarrow {}^{m}_{n}\mathbf{X} + {}^{1}H$$

(i) Write the full nuclide notation of atom **X** in the form $^{m}_{n}\mathbf{X}$.

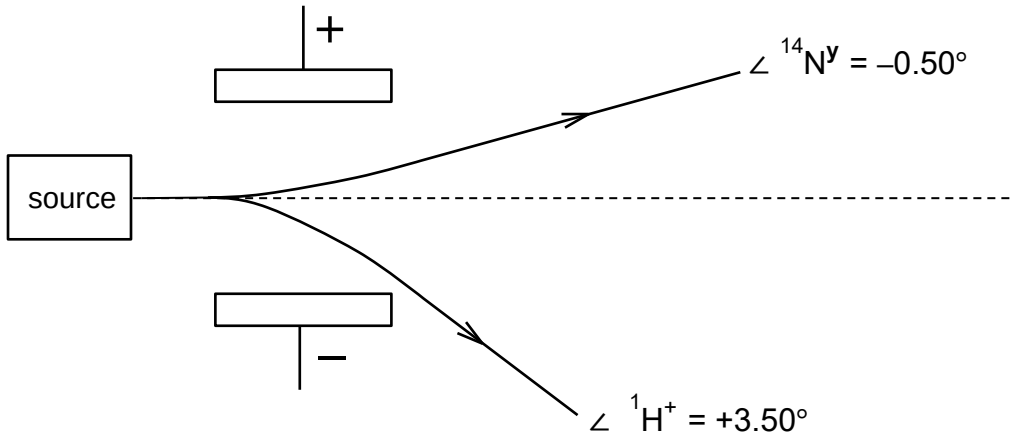
..... [1]

(ii) Explain whether ^{14}N and $^{m}_{n}\mathbf{X}$ are isotopes.

.....

..... [1]

(d) $^{1}H^{+}$, $^{m}_{n}\mathbf{X}^{-}$ and $^{14}N^{\mathbf{y}}$ are passed through an electric field.



(i) Calculate the charge of $^{14}N^{\mathbf{y}}$, **y**.

[1]

(ii) Calculate the angle of deflection of $^{m}_{n}\mathbf{X}^{-}$ (to 2 d.p.).

[1]

(iii) Complete the diagram above by drawing the deflection pathway of $^{m}_{n}\mathbf{X}^{-}$.
Label the path with an arrow and the angle of deflection.

[1]

[Total: 9]

3 Pnictogens are Group 15 elements.

They can form molecular compounds with hydrogen, forming pnictogen hydrides with the formula $\mathbf{Z}H_3$ where **Z** refers to a pnictogen atom.

Table 3.1

pnictogen hydride, $\mathbf{Z}H_3$	element of **Z**	atomic radius of **Z** / nm	bond length of **Z**–H / nm	boiling point of $\mathbf{Z}H_3$ / °C
?	nitrogen	155	102	–33
phosphine	phosphorus	180	142	–88
arsine	arsenic	185	152	–63
stibine	antimony	206	171	–17

(a) Name the first pnictogen hydride.

..... [1]

(b) **(i)** The first pnictogen hydride has a boiling point that does not follow the trend of pnictogen hydrides down the Group.

Draw a labelled diagram to show the interaction that results in this anomalous boiling point.

[2]

(ii) Phosphorus, arsenic, antimony and hydrogen have very similar electronegativity values.

Using structure and bonding, explain the boiling point trend for phosphine, arsine and stibine.

……..

……

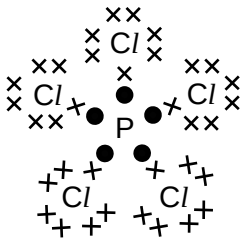
……

……

……

……... [3]

(c) Besides phosphine, phosphorus forms many other derivative compounds.
Complete the table below.

	PCl_3	$POCl_3$	PCl_5
dot-and-cross diagram			
molecular shape around P atom		tetrahedral	
polar or non-polar?		polar	

[4]

(d) State and explain the trend of the atomic radii of **Z** down Group 15.

.....

.....

.....

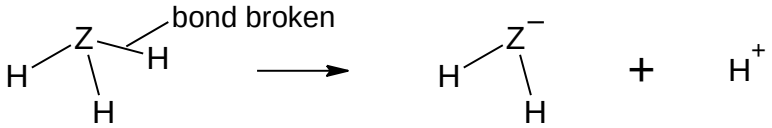
..... [2]

(e) Pnictogen hydrides exhibit acid-base behaviour.

(i) Write an ionic equation to show how phosphine behaves as a Brønsted-Lowry base in water (state symbols are not required).

…….…….……..... [1]

(ii) Pnictogen hydrides can also behave as Brønsted-Lowry acids.



Using information in **Table 3.1** and your answer in **(d)**, state and explain which of the four pnictogen hydrides listed in **Table 3.1** is the strongest Brønsted-Lowry acid.

……..

……..

……..

……..

……... [3]

[Total: 16]

4 Gallium is a Group 13 metal. It forms a compound with chlorine, $GaCl_3(s)$.

$GaCl_3(s)$ is either an ionic compound or a molecular compound.

(a) *Use of the Data Booklet is relevant to this question.*

Assuming $GaCl_3(s)$ is an ionic compound, calculate the enthalpy change of formation of $GaCl_3(s)$. Draw a Born-Haber energy cycle to illustrate your working.

enthalpy change of atomisation of gallium / kJ mol^{-1}	+277
electron affinity of chlorine atom / kJ mol^{-1}	–349
lattice energy of $GaCl_3(s)$ / kJ mol^{-1}	–5217

[4]

(b) Some experimentally-determined data of $GaCl_3(s)$ are shown:

enthalpy change of formation	–884 kJ mol^{-1}
melting point	78 °C
boiling point	204 °C

Using structure and bonding, explain why $GaCl_3(s)$ shows such unexpected melting and boiling points.

.....

.....

.....

..... [2]

[Total: 6]

5 Sodium chloride dissolves completely in water to form a colourless solution.

(a) Using the data below, construct an appropriate energy cycle to calculate the enthalpy change of hydration of chloride ion.

enthalpy change of solution of NaC*l* / kJ mol^{-1}	+3
enthalpy change of hydration of sodium ion / kJ mol^{-1}	–406
lattice energy of NaC*l* / kJ mol^{-1}	–787

[3]

(b) The enthalpy change of solution of NaC*l* is endothermic under standard conditions.

This implies that the energy released by the formation of ion-dipole forces of attraction between ions and water molecules is not sufficient to overcome the electrostatic forces of attraction between the oppositely-charged ions in sodium chloride.

With reference to the changes in entropy and Gibbs free energy, explain how dissolving sodium chloride is spontaneous despite being endothermic.

.....

.....

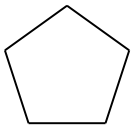
.....

.....

..... [3]

[Total: 6]

6 Cyclopentane (C_5H_{10}) is a cyclic hydrocarbon.



cyclopentane

(a) State the type of hybridisation of each carbon atom in cyclopentane.

..... [1]

(b) Draw two constitutional isomers of cyclopentane.

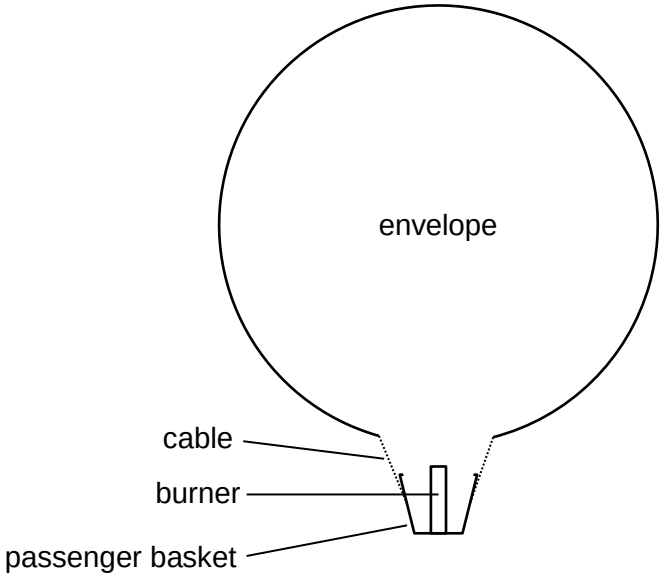
[2]

[Total: 3]

7 Hot-air balloons consist of an envelope suspending a passenger basket.

A burner at the centre of the basket vaporises liquid propane and combusts it, releasing heat energy into the envelope to heat up the air inside.

The envelope has a fixed volume and is open to atmospheric air at the bottom, allowing the heated air to maintain the same pressure as the surroundings.



Envelope specifications

Air volume	:	2800 m^3
Material (inner lining)	:	Nylon (melting point: 269 °C)
Material (inlet ring)	:	fire-resistant Nomex (up to 370 °C)

Air

Composition of atmospheric air :

gas	% by volume	M_r
N_2	78.08	28.0
O_2	20.95	32.0
Ar	0.93	39.9
CO_2	0.04	44.0
weighted average M_r		28.96

Specific heat capacity of air : 1.012 J g^{-1} $°C^{-1}$

Burner specifications

Fuel	:	liquefied propane (C_3H_8)
Enthalpy change of combustion of fuel	:	–2220 kJ mol^{-1}
Density of liquid fuel	:	0.493 g cm^{-3}

(a) **(i)** Prove that the density of atmospheric air at 25.0 °C is 1184.94 g m^{-3}.
Assume that air behaves ideally.

[1]

In order for the hot-air balloon to generate enough lift, the density of the heated air inside the envelope must decrease to 948.72 g m^{-3}.

To achieve this density, the air inside the envelope must be heated to 99.2 °C.

As the air in the envelope is heated, it expands and leaves from the opening at the bottom.

(ii) Assuming that the air in the envelope decreases in density at a constant rate, calculate the average density of the air in the envelope (in g m^{-3}) as it was heated from 25.0 °C to 99.2 °C (to 2 d.p.).

[1]

(iii) Calculate the average mass (in g) of the air as it was being heated in the envelope from your answer in **(ii)** (to the nearest whole number).

[1]

(iv) Using your answer in **(iii)**, calculate the heat energy required (in J) to heat up the air in the envelope to the required temperature (to the nearest whole number).

[1]

(v) Calculate the volume of liquefied fuel that must be burnt to provide the heat energy found in **(iv)** (to 3 s.f.).

[2]

(b) In order for the hot-air balloon to generate enough lift, the density of the air in the envelope must be significantly lower than the external air density.

The density of air decreases with increasing temperature.

Explain why it is unsafe to fly the hot-air balloon on a warm day.

.....

.....

..... [1]

(c) Some hot-air balloons may replace part of the air in the envelope with helium.

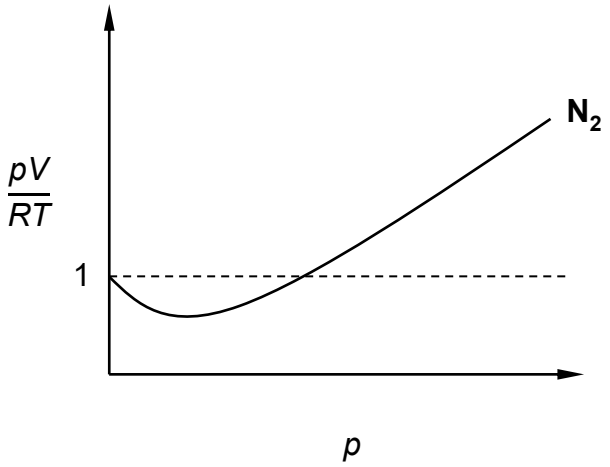
(i) Explain whether helium behaves more or less ideally than the atmospheric gases.

……

……

…….... [1]

(ii) Sketch a graph on the axes below to show how 1.00 mol of helium compares to 1.00 mol of nitrogen in terms of its ideality.



[1]

[Total: 9]

END OF SECTION B

END OF PAPER 1

BLANK PAGE

BLANK PAGE