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

Section A – Multiple Choice

1	2	3	4	5
B	**B**	**C**	**D**	**D**
6	7	8	9	10
A	**C**	**B**	**D**	**B**
11	12	13	14	15
A	**C**	**A**	**C**	**C**

1

1	Correct. Empirical formula is the lowest whole number ratio of the number of atoms of each element.
2	Correct. Molecular formula is the number of atoms of each element present in one molecule.
3	Not correct. The relative molecular mass of C_6H_{12} is **72.0 + 12.0 = 84.0**, not 48.0. Relative molecular masses are calculated by summing the relative atomic masses of each element found in the Periodic Table, multiplied by the number of atoms.

2

	C_xH_y	+	$(x+\frac{y}{4})\ O_2$	$\longrightarrow$	$x\ CO_2$	+	$\frac{y}{2}\ H_2O$
initial volume / cm^3	10		90		0		
change in volume / cm^3	-10		**-50**		**+30**		
final volume / cm^3	0		40		**30**		

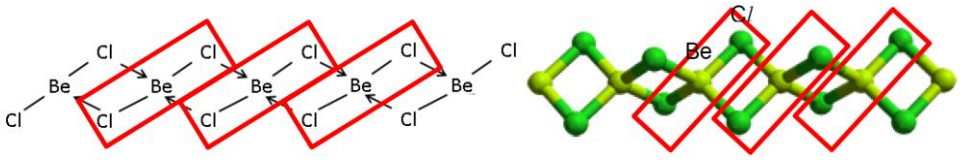
volume of oxygen gas unreacted = 40 cm^3
volume of carbon dioxide gas formed = 70 – 40 = **30 cm^3**

volume of oxygen reacted = 90 – 40 = **50 cm^3**

$\eta_{C_xH_y} : \eta_{O_2} : \eta_{CO_2}$
= **10 : 50 : 30**
= 1 : 5 : 3
= $1 : x+\frac{y}{4} : x$

hence x = 3
$x+\frac{y}{4} = 5$
y = 8
Molecular formula of hydrocarbon is C_3H_8.

3

A	Not correct. $BeCl_2$ is a linear molecule. Be only has 2 valence electrons, and forms two bond pairs with C*l*. Be has no lone pairs of electrons. Hence the two electron domains around Be form a 180° from each other.
B	Not correct. $BeCl_2$ is a molecule. Be^{2+} ion has a high charge density, strongly polarising Cl^- ion electron clouds towards itself, forming Be–C*l* covalent bonds.
C	Correct. Be has an electronic configuration of $1s^2\ 2s^2$. To form 2 bonds, its valence orbitals (2s and 2p) undergo sp hybridisation, forming 2 sp orbitals which form covalent bonds with C*l* atoms. Be hence has 2 energetically-accessible vacant unhybridised 2p orbitals which can **accept lone pairs of electrons** from chlorine atoms, forming a polymer. 
D	Not correct. The 1s orbital of Be is fully-filled and cannot accept additional electrons.

4 $2Zn(NO_3)_2(s) \longrightarrow 2ZnO(s) + 4NO_2(g) + O_2(g)$
$+5\ -2 \qquad\qquad +4 \qquad 0$

$Zn(NO_3)_2$ was oxidised to form O_2.
The oxidation state of O increased from -2 (in $Zn(NO_3)_2$) to 0 (in O_2).

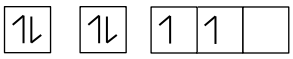
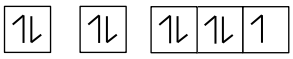
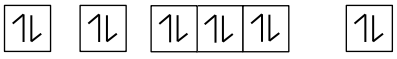
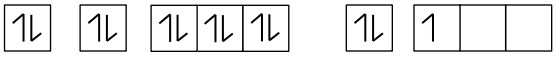
$Zn(NO_3)_2$ was also reduced to form NO_2.
The oxidation state of N decreased from +5 (in $Zn(NO_3)_2$) to +4 (in NO_2).

5 Ground-state electronic configuration of C*l*: $1s^2\ 2s^2\ 2p^6$ **$3s^2\ 3p^5$**

Excited-state electronic configuration of C*l*: $1s^2\ 2s^2\ 2p^6\ 3s^1\ 3p^6$

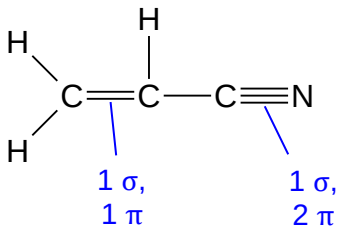
One electron must have transferred from 3s (lower energy) to 3p (higher energy).

6

	element	electronic configuration	number of half-filled orbitals
A	C		**2**
B	F		1
C	Mg		0
D	A*l*		1

7 The first bond between two atoms is a sigma (σ) bond.

Any bond formed in excess of the first one is a pi (π) bond.



8 melting point of ionic compound ∝ LE ∝ $\left|\frac{q_+ \times q_-}{r_+ + r_-}\right|$

Since O^{2-} and F^- ions have similar ionic radii (F^- ion 0.136 nm is much larger than half the radius of O^{2-} ion 0.140 nm), only the magnitudes of q_+ and q_- will result in significant differences in lattice energies.

	compound	$q_+ \times q_-$	melting point
A	CaF_2	$+2 \times -1 = -2$	
B	CaO	$+2 \times -2 = -4$	highest
C	K_2O	$+1 \times -2 = -2$	
D	KF	$+1 \times -1 = -1$	

9

A	Not correct. All boron and nitrogen atoms in the network use up all of their available valence electrons to form covalent bonds. Hence there are no delocalised electrons to behave as mobile charge carriers.
B	Not correct. Only metals are ductile and malleable. Boron nitride resembles graphite in structure, which has a giant molecular structure.
C	Not correct. Boron nitride is a soft material. Between planes of boron and nitrogen atoms, there are weak instantaneous dipole-induced dipole forces of attraction, which require little energy to overcome and allows the planes to slide over one another easily.
D	Correct. The atoms of boron and nitrogen are held together in a network by strong covalent bonds. These bonds require much energy to break before the substance can melt.

10 Metals are ductile and malleable.

Only metals are able to conduct electricity in solid state. This is achieved by the 'sea' of delocalised electrons surrounding the metal ion lattice, acting as mobile charge carriers.

	melting point / °C	electrical conductivity in different states			identity of substance
		(s)	(*l*)	(aq)	
A	122	×	×	✓	$C_6H_5CO_2H$
B	181	✓	✓	insoluble	**Li**
C	373	×	✓	insoluble	$PbBr_2$
D	802	×	✓	✓	NaC*l*

11

A	Correct. The volume of the gas measured is assumed to only consist of the space containing the gas, and does not include the volume that the gas molecules themselves occupy.
B	Not correct. A gas is most ideal under **low pressure** and **high temperature**, so that molecules are sufficiently far apart and can overcome the forces of attraction between molecules.
C	Not correct. Ideal gas molecules collide **perfectly elastically** – kinetic energy is conserved in all the molecules.
D	Not correct. The correct ideal gas assumption is 'forces of attraction between molecules are insignificant', and makes no mention about the type of force.

12 Standard temperature and pressure refers to 273 K (0 °C) and 100000 Pa (1 bar).

V_1 = 3.00 dm^3
P_1 = 300 kPa
P_2 = 100 kPa

Since only p and V varied while n and T remained constant, the relationship $p_1V_1 = p_2V_2$ should be used.

$(300\ kPa)(3.00\ dm^3) = (100\ kPa)(V_2)$
Hence V_2 = **9.00 dm^3**

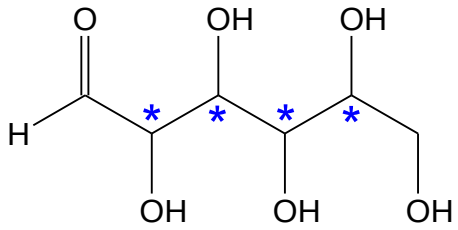
13

A	Since $pV = nRT$ and $p \propto T$, the graph showing a direct proportional relationship is correct.
B	Since $pV = nRT$ and $pV \propto T$, pV is therefore inversely proportional to $\frac{1}{T}$ and the graph of a direct proportional relationship is not correct. The graph should be an inverse relationship.
C	Since $pV = nRT$ and $V = nRT(\frac{1}{p})$, $\frac{1}{p} = \frac{1}{nRT}V$. Therefore $\frac{1}{p} \propto V$ and the graph of an inverse relationship is not correct. The graph should be a direct proportional relationship.
D	Since $pV = nRT$ and $V \propto T$, the graph of an inverse relationship is not correct. The graph should be a direct proportional relationship.

14 Since $pV = nRT$, nR is the gradient of the graphs.
gradient = $nR = \frac{m}{Mr}R$

gas	Mr	rank in Mr	rank in $\frac{m}{Mr}R$
N_2	28.0	3rd	2nd
O_2	32.0	2nd	**3rd**
Ar	39.9	1st	4th
CH_4	16.0	4th	1st

15



There are 4 chiral carbon atoms in the D-glucose molecule.

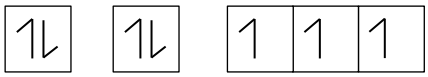
Therefore, number of enantiomers in total = 2^4 = **16**.

Section B – Structured Questions

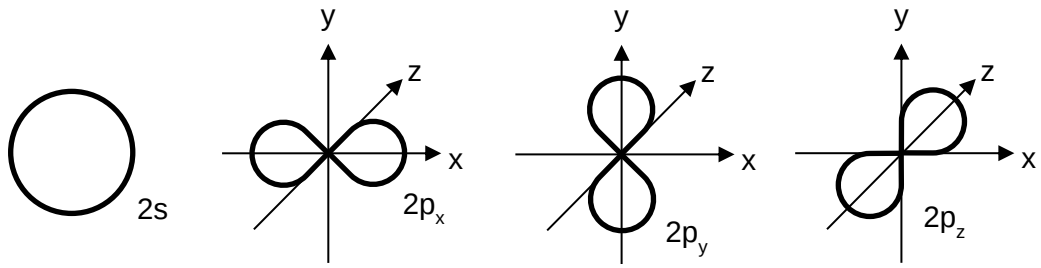
1	**(a)**		$MnO_4^- + 8\ H^+ + 5\ e^- \longrightarrow Mn^{2+} + 4\ H_2O$ $2\ I^- \longrightarrow I_2 + 2\ e^-$
	(b)		$I_2 + 2\ S_2O_3^{2-} \longrightarrow 2\ I^- + S_4O_6^{2-}$
	(c)		$\eta_{S_2O_3^{2-}} = \frac{24.90}{1000}$ dm^3 × 1.50 mol/dm^3 = 0.03735 mol since $\frac{\eta_{I_2}}{\eta_{S_2O_3^{2-}}} = \frac{1}{2}$ ecf (b) coefficients $\eta_{I_2} = \frac{1}{2}$ × 0.03735 mol = 0.018675 mol = **0.0187 mol**
	(d)		since $\frac{\eta_{e^-}}{\eta_{I_2}} = \frac{2}{1}$ ecf (a) coefficients η_{e^-} = 2 × <u>0.018675 mol</u> = 0.03735 mol ecf (c) since $\frac{\eta_{MnO_4^-}}{\eta_{e^-}} = \frac{1}{5}$ ecf (a) coefficients $\eta_{MnO_4^-} = \frac{1}{5}$ × 0.03735 mol = **0.00747 mol** accept 0.00748 if 0.0187 used from (c)
	(e)		[MnO_4^-] = $\frac{0.00747\ mol}{\frac{10.0}{1000}\ dm^3}$ = **0.747 mol dm^{-3}** ecf (d) accept 0.748 if 0.0187 used from (c)

2 (a) **endothermic**
energy / cosmic ray
is **absorbed** / required
to **break** the covalent **bond**

(b) (i)



(ii)



3 sets of axes: 1 point each
4 shapes + label: 1 point each

7 / 7 points: [2]
4 / 7 points: [1]

ecf (i) 3s, 3p

(c) (i) $^{14}_{6}C$ accept X

(ii) **no**
they have **different number of protons** / are of different elements

ecf from (c)(i):
yes, they have the same number of protons but different number of neutrons /
no, they are the same isotope / have the same number of neutrons

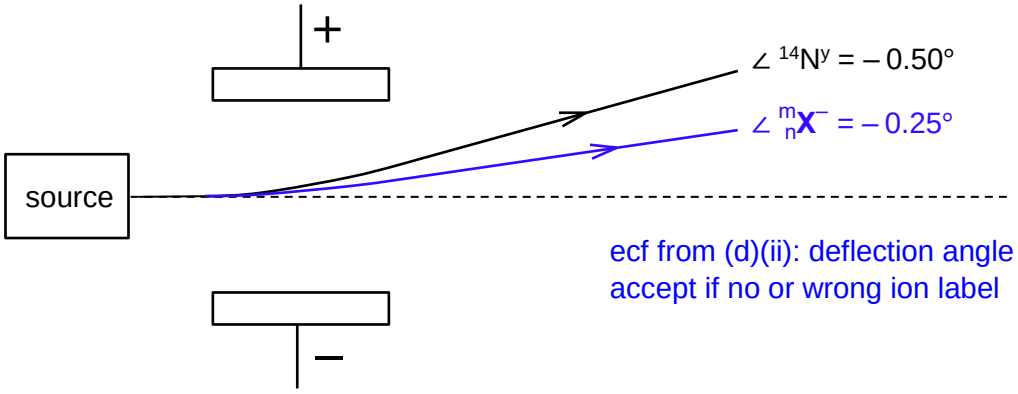
(d) (i) $\angle\ ^{1}H^{+} = \frac{kz}{m} = \frac{k(+1)}{1} = +3.50°$
hence k = 3.5

$\angle\ ^{14}N^{y} = \frac{kz}{m} = \frac{(3.5)(y)}{14} = -0.50°$
hence y = **2–** or –2

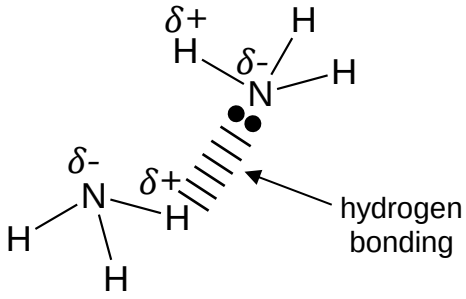
(ii) $\angle\ ^{m}_{n}X^{-} = \frac{kz}{m} = \frac{(3.5)(-1)}{14} =$ **–0.25°** or 0.25°

ecf from (c)(i): value of m if not 14
ecf from (d)(i): value of k if not 3.5

(iii)



ecf from (d)(ii): deflection angle
accept if no or wrong ion label

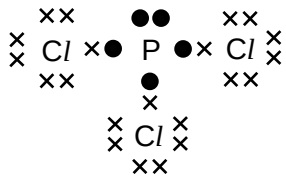
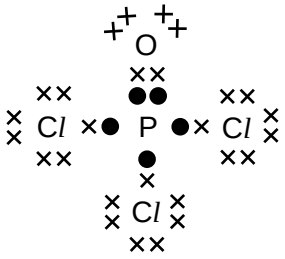
<table>
<tr><td>3</td><td>(a)</td><td colspan="4">ammonia</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td></td><td> 
</td><td>1 point each:
lone pair of electrons on N (1)
dashed lines (2)
label of the interaction (3)
δ+ δ– on involved atoms (4)

either one:
δ+ δ– complete the two pairs (5)
both correct structural formulae of NH_3 (6)

5 / 5 points: [2]
3 / 5 points: [1]</td></tr>
<tr><td></td><td></td><td>(ii)</td><td></td><td colspan="2">simple molecular structure (1)
with instantaneous dipole-induced dipole forces / attractions (2) (between molecules)
more electrons / larger electron clouds from PH_3 < AsH_3 < SbH_3 (3)
stronger / greater extent of forces (4) (mark points separately)
requiring more energy to overcome (5)

5 / 5 points: [3]
3 / 5 points: [2]
1 / 5 points: [1]</td></tr>
</table>

(c)

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

ecf molecular shape and polarity for PCl_3 only:
based on number of bond pairs and lone pairs in the dot-and-cross diagram

each dot-and-cross diagram: 2 points
each molecular shape and polarity: 1 point

8 / 8 points: [4]
6 / 8 points: [3]
4 / 8 points: [2]
2 / 8 points: [1]

(d)

although nuclear charge and shielding increase (1)
distance between valence electrons and nucleus increases (2)
<u>electrostatic forces</u> / <u>attractions</u> between them are weaker (3)
atomic radius down the Group increases (4) accept if given in (e)(ii)

4 / 4 points: [2]
2 / 4 points: [1]

(e) **(i)**

$PH_3 + H_2O \rightleftharpoons PH_4^+ + OH^-$ /
$PH_3 + H^+ \rightleftharpoons PH_4^+$

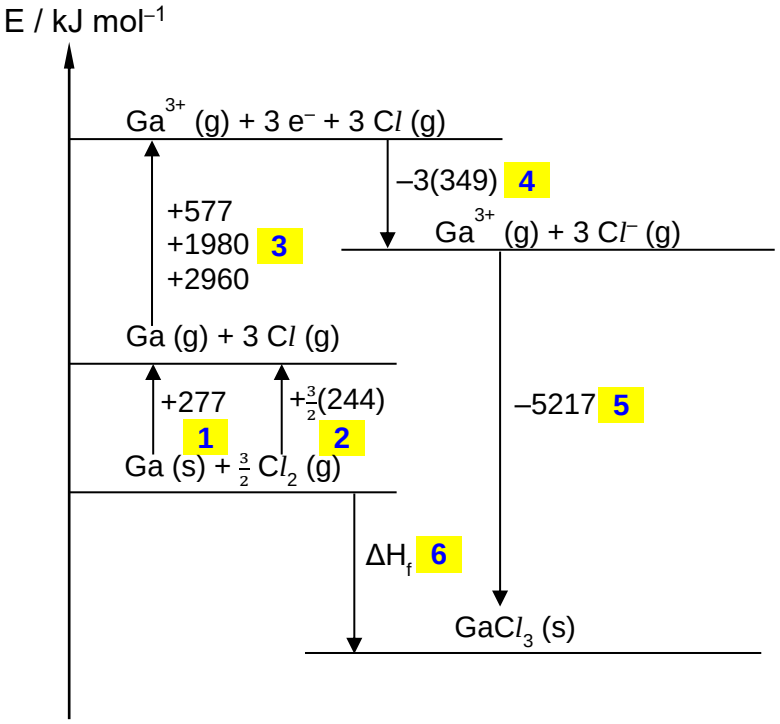
accept $\longrightarrow$

(ii)

SbH_3 (1)
Sb–H bond is the longest (2)
lowest extent of orbital overlap (3)
weakest bond (4)
lowest bond energy / easiest to break (5)
highest percentage of molecules will dissociate /
greatest ease of dissociation / formation of H^+ (6)

6 / 6 points: [3]
4 / 6 points: [2]
2 / 6 points: [1]

4 **(a)**



each correct process
1 point

eg.

$\frac{3}{2}\,Cl_2\,(g) \xrightarrow{+\frac{3}{2}(244)} 3\,Cl\,(g)$

6 / 6 points: [3]
4 / 6 points: [2]
2 / 6 points: [1]

ΔH_f = + 277 + $\frac{3}{2}$(244) + 577 + 1980 + 2960 – 3(349) – 5217 = **–104 kJ mol^{-1}** [1]

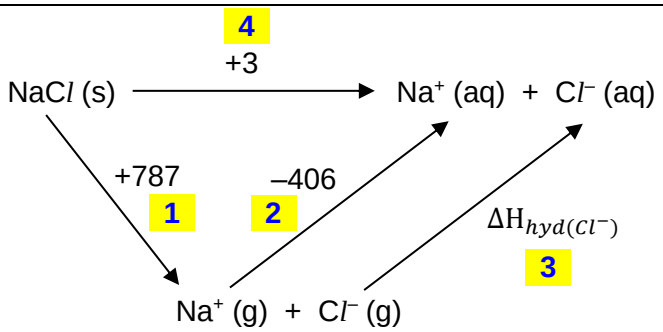
ecf for calculations: any wrong values in the diagram

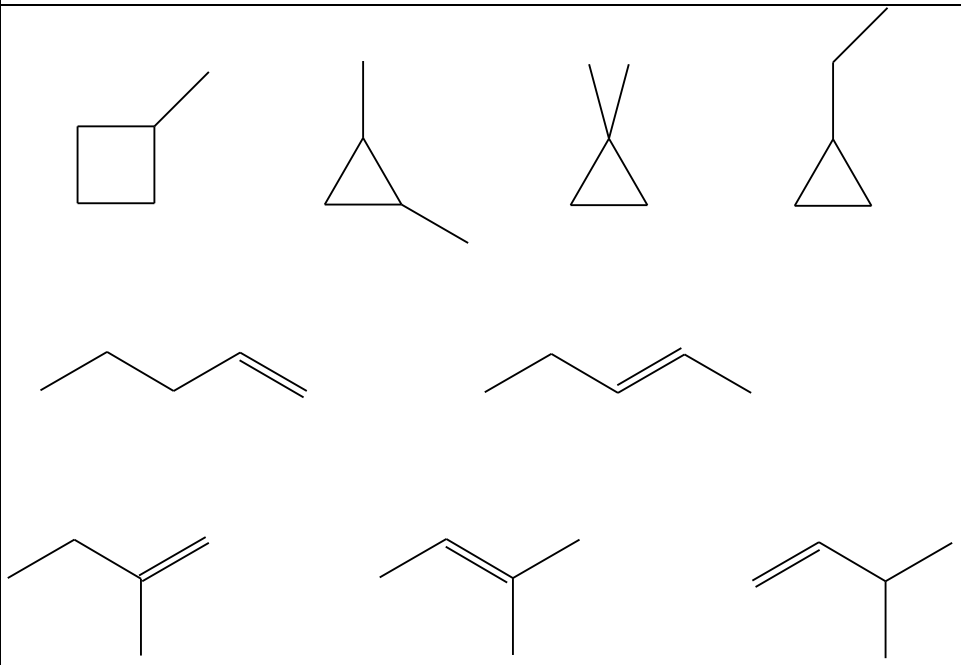
For missing electrons, both IE and EA steps will be penalised
That is, wrong mole / missing state symbol, both steps before and after will not be awarded.

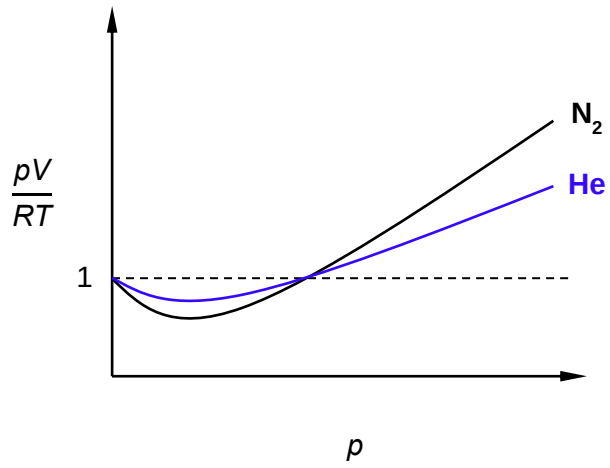
(b)

$GaCl_3$ has simple molecular structure (1)
instantaneous dipole-induced dipole forces / attractions (2) (between molecules)
id-id are weak (3)
requiring little energy to overcome (4)

4 / 4 points: [2]
2 / 4 points: [1]

5	**(a)**		 + 787 – 406 + ΔH$_{hyd(Cl^-)}$ = + 3 ΔH$_{hyd(Cl^-)}$ = **–378 kJ mol^{-1}** [1] ecf for calculations: any wrong values in the diagram each correct process 1 point eg. NaCl(s) $\xrightarrow{+787}$ Na⁺(g) + Cl⁻(g) 4 / 4 points: [2] 2 / 4 points: [1]
	(b)		mixing / increased number of particles / increased freedom of movement / increased degrees of freedom / more ways to arrange particles / disorder increases **(1) – (2) for any two** entropy increases / ΔS is positive **(3)** (–TΔS is negative / TΔS is positive) |TΔS| is larger than |ΔH| / negative term is larger (in magnitude) **(4)** hence ΔG is negative **(5)** 5 / 5 points: [3] 3 / 5 points: [2] 1 / 5 points: [1]

6	**(a)**		sp^3
	(b)		 mark the first 3 molecules given (read from left to right, line by line) if no correct answers are given in the first 3 molecules, max 1 m if any subsequent molecules are correct

7	**(a)**	**(i)**	$pV = \frac{m}{Mr}RT$ density = $\frac{m}{V} = \frac{pMr}{RT} = \frac{(\mathbf{101325})(\mathbf{28.96})}{(\mathbf{8.31})(\mathbf{298})}$ = 1184.94 g m^{-3}		correct substitutions
		(ii)	average air density = $\frac{1184.94+948.72}{2}$ = **1066.83 g m^{-3}**		ecf from (i)
		(iii)	average mass of heated air = 1066.83 g/m^3 × 2800 m^3 = **2 987 124 g**		ecf from (ii)
		(iv)	Q = mcΔT = (2987124)(1.012)(99.2 – 25.0) = **224 304 336 J**		ecf from (iii)
		(v)	$\eta_{C_3H_8} = \frac{224304336\times10^{-3}\ kJ}{2220\ kJ/mol}$ = **101.038 mol** [1] mass of C_3H_8 = 101.038 mol × 44.0 g/mol = 4445.67 g volume of C_3H_8 = $\frac{4445.67\ g}{0.493\ g/cm^3}$ = 9017.5 cm^3 = **9020 cm^3** (3 s.f.) [1]		ecf from (iv)
	(b)		either explanation: the envelope air must be heated to an even **higher temperature** which may **melt / damage** the envelope / **less difference** between external and internal air density **less lift**		
	(c)	**(i)**	**more ideal** helium has **few electrons** / 2 electrons / a small electron cloud hence has either: **weaker** / less significant **instantaneous dipole-induced dipole forces** / attractions or: an **insignificant** / small **atom volume**		
		(ii)			helium curve lower than nitrogen on the right-hand side ecf (i) He less ideal reject horizontal line accept if no label accept if no negative deviation

END OF SECTION B

END OF PAPER 1