Class | Adm No

Candidate Name: _____

H

millennia institute

2022 End-of-Year Examination
Pre-University 1

H2 CHEMISTRY **9729/01**

Paper 1 Multiple Choice & Structured Questions **12 Oct 2022**

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	Section B						**Total**
		1	2	3	4	5	6	
Marks	15	10	12	10	8	9	6	**70**

DA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	8.3%	5.8%	5.8%	28.9%	71.1%	16.5%	14.0%	9.9%	0.0%	9.9%	18.2%	8.3%	24.0%	15.7%	24.0%
B	6.6%	72.7%	19.8%	7.4%	15.7%	4.1%	51.2%	14.9%	0.0%	32.2%	40.5%	18.2%	63.6%	43.0%	36.4%
C	36.4%	12.4%	21.5%	44.6%	8.3%	69.4%	23.1%	11.6%	57.0%	14.0%	26.4%	62.0%	10.7%	9.1%	25.6%
D	48.8%	9.1%	52.1%	19.0%	4.1%	9.9%	9.9%	63.6%	43.0%	40.5%	13.2%	10.7%	1.7%	29.8%	13.2%

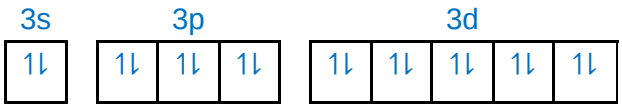
Qn	Distractor
4	C – Higher M_r of ethanoic acid is due to formation of dimer via H-bonding in non-polar benzene solvent.
7	B – Did not account for original 8 dm^3 in new total volume C – Did not account for the 9 dm^3 added to new total volume
9	C – Careless, 1 mol must compare to 1 mol

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.

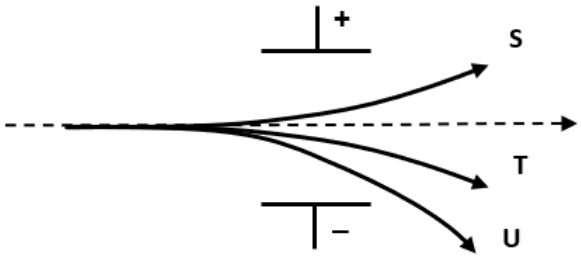
1 How many subshells and orbitals are there in principal quantum shell number 3?

	subshells	orbitals
A	2	4
B	2	6
C	3	6
D	3	9



2 *Use of the Data Booklet is relevant to this question.*

The following are flight paths of charged particles when accelerated in an electric field.



Which correctly identifies **S**, **T** and **U**?

	S	**T**	**U**
A	$^{14}N^{+}$	$^{14}C^{-}$	$^{14}C^{2-}$
B	$^{14}N^{-}$	$^{12}C^{+}$	$^{12}C^{2+}$
C	$^{12}C^{-}$	$^{14}N^{2+}$	$^{14}N^{+}$
D	$^{14}C^{-}$	$^{12}C^{+}$	$^{14}N^{+}$

S must be negatively charged (attracted to positive terminal), **T** & **U** must be positively charged (attracted to negative terminal).
U must have a larger $\frac{q}{m}$ ratio compared to **T** due to its larger deflection angle.

3 In microwave ovens, the energy produced is absorbed by polar molecules.

Which of the following would absorb microwave energy?

1 CO_2

2 BrF_3

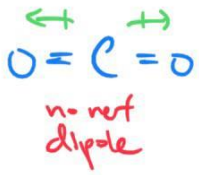
3 BF_3

4 SO_2

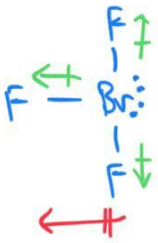
A 1 and 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 2 and 4 only

To determine if a molecule is polar, the following must be done in sequence:
1. Draw structure with correct shape (if not familiar, you may have to start from dot-and-cross)
2. Identify all individual bond dipoles
3. Check for net dipole moment

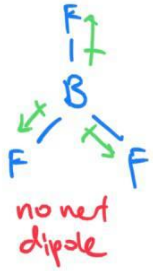
CO_2
2bp 0lp
linear



BrF_3
3bp 2lp
T-shape



BF_3
3bp 0lp
trigonal planar



SO_2
2bp 1lp
bent

4 Which of the following **cannot** be explained by hydrogen bonding?

A the difference in boiling point between ethanol and hexan-1-ol

B the difference in melting point between H_2O and HF

C the higher than expected relative molecular mass of ethanoic acid in benzene

D the difference in density between water and ice

Boiling point: ethanol < hexan-1-ol
Same average no. of H-bonds per molecule (1), also same polarity of O–H bond. Similar H-bonding strength. Difference in boiling point is due to large electron cloud size of hexan-1-ol leading to stronger id-id IMFOA.

Melting point: H_2O > HF
H_2O has an average of 2 H-bonds per molecule compared to the 1 of HF, hence stronger H-bonding.

Higher M_r of ethanoic acid is due to formation of dimer via H-bonding in non-polar benzene solvent.

Density: water > ice
Lower density of ice is due to its open structure, which results from the orderly tetrahedral arrangement of its molecules H-bonded to each other.

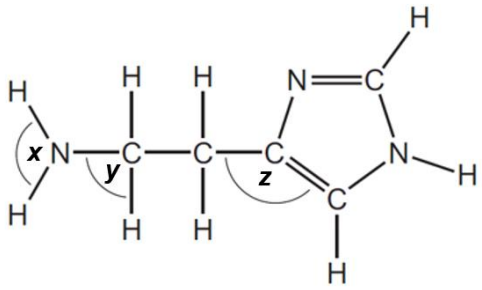
5 Trifluorooxonium has the formula OF_3^{n+} and its shape is trigonal pyramidal.

What is the value of *n* in trifluorooxonium?

A 1 **B** 2 **C** 3 **D** 4

F atoms will only form single bonds to O.
Trigonal pyramidal → 3bp 1lp → 5 val e^- on O → 1 less than usual 6, thus n=1.

6 Histamine is produced in the body to help fight infection. Its shape allows it to fit into receptors which expand blood vessels.



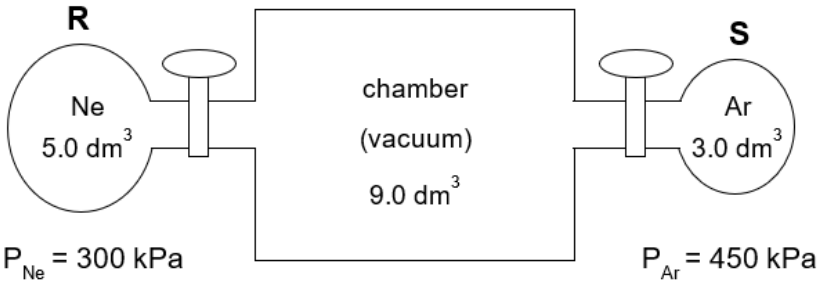
histamine

What are the values of the bond angles ***x***, ***y*** and ***z***?

	x	***y***	***z***
A	120°	90°	120°
B	109°	109°	107°
C	107°	109°	120°
D	107°	120°	109°

x – 3bp 1lp (trigonal pyramidal)
y – 4bp 0lp (tetrahedral)
z – 3bp 0lp (trigonal planar)

7 Two bulbs **R** and **S**, containing Ne and Ar respectively, are connected to a 9 dm^3 vacuum chamber as shown.



What will be the total pressure in the vessel when the valves are opened at constant temperature?

A 168 kPa **B** 317 kPa **C** 356 kPa **D** 375 kPa

$n_T = n_R + n_S$
at constant T,
$P_TV_T = P_RV_R + P_SV_S$
$P_T(17.0\ dm^3) = (300\ kPa)(5.0\ dm^3) + (450\ kPa)(3.0\ dm^3)$
$P_T = 168\ kPa$ (3sf)

8 In which reactions does NH_3 behave as a Brønsted-Lowry acid?

1 $HSO_4^- + NH_3 \rightarrow SO_4^{2-} + NH_4^+$

2 $Ag^+ + 2NH_3 \rightarrow [Ag(NH_3)_2]^+$

3 $NH_3 + PO_4^{3-} \rightarrow NH_2^- + HPO_4^{2-}$

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

1: NH_3 becomes NH_4^+ (H^+ acceptor, base)
2: NH_3 stays as NH_3 (not acid-base reaction)
3: NH_3 becomes NH_2^- (H^+ donor, acid)

9 Which of the following correctly defines the term *relative atomic mass* of an element?

A the mass of 1 atom of an element relative to the mass of 1 atom of ^{12}C

B the mass of 1 mole of atoms of an element divided by 6.02×10^{23}

C the mass of 1 mole of atoms of an element relative to $\frac{1}{12}$ the mass of 1 atom of ^{12}C

D the mass of 1 mole of atoms of an element relative to $\frac{1}{12}$ the mass of 1 mole of ^{12}C atoms

Definition question.

10 A carbon sample contains a mixture of ^{12}C and ^{14}C isotopes. When 1.000 g of this sample is burned completely in $^{16}O_2$, the mass of CO_2 formed is 3.55 g.
What is the percentage by mass of the ^{12}C isotope in this sample?

A 12.4% **B** 30.6% **C** 50.5% **D** 69.4%

	$^{12}C + O_2 \rightarrow {}^{12}CO_2$	$^{14}C + O_2 \rightarrow {}^{14}CO_2$
Mass of C / g	x	$1-x$
Amount of C / mol	$\frac{x}{12}$	$\frac{1-x}{14}$
Amount of CO_2 / mol	$\frac{x}{12}$	$\frac{1-x}{14}$

Mass of CO_2 formed = Mass of $^{12}CO_2$ + Mass of $^{14}CO_2$

$$3.55 = \left[\frac{x}{12} \times (12 + 32)\right] + \left[\frac{1-x}{14} \times (14 + 32)\right]$$

$$3.55 = \frac{44}{12}x + \frac{46}{14} - \frac{46}{14}x$$

x = 0.6937 g

$$\% \text{ by mass of } {}^{12}C = \frac{0.6937}{1} \times 100\%$$

= 69.4% (3sf)

11 An ion of metal **M** can be oxidised by potassium manganate(VII) in acid solution to form $\mathbf{M}O_3^-$. In an experiment, 0.00500 mol of the ion of **M** required 15.0 cm^3 of 0.200 mol dm^{-3} potassium manganate(VII) for complete reaction.

What is the initial oxidation state of the ion of **M** given that potassium manganate(VII) is reduced to Mn^{2+}?

A +1 **B** +2 **C** +4 **D** +7

[R]: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
[O]: $\mathbf{M}^n \rightarrow \mathbf{M}^{5+} + e^-$

Amount of MnO_4^- = $0.200 \times \frac{15.0}{1000}$
= 0.003 mol
Amount of e^- gained in [R] = 0.003 x 5
= 0.015 mol
= Amount of e^- lost in [O]
Amount of $\mathbf{M}^n$ = 0.005 mol
Mole ratio of $\mathbf{M}^n$:e^- = 1:3

[O]: $\mathbf{M}^n \rightarrow \mathbf{M}^{5+} + 3e^-$
n = +2

12 *Use of the Data Booklet is relevant to this question.*

When 0.85 g of ethanol (M_r = 46.0) was burnt completely under a container containing 350 g of water, the temperature of the water rises by 10 °C.

The enthalpy change of combustion of ethanol is –1367 kJ mol^{-1}.

What is the efficiency of this reaction?

A 6.10% **B** 42.1% **C** 57.9% **D** 93.9%

Let x be the efficiency of reaction.
$Q_{x\%}$ = mcΔT
= (350)(4.18)(10)
= 14630 J
= 14.63 kJ
$Q_{100\%} = -\Delta H_c \times n_{ethanol}$
$= 1367 \times \frac{0.85}{46.0}$
= 25.259 kJ
$x = \frac{14.63}{25.259} \times 100\%$
= 57.9% (3sf)

13 In cars, internal combustion engines convert the chemical energy in fuels into kinetic energy.

The following reaction takes place in an internal combustion engine.

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$$

Which of the following statements are correct about the reaction?

1 Enthalpy change of the reaction is negative.

2 Entropy change of the reaction is negative.

3 The reaction is spontaneous at all temperatures

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

1: combustion reactions are almost always exothermic: $\Delta H < 0$
2: $\Delta n = +9$, increase in no. of gaseous particles, increase in entropy: $\Delta S > 0$
3: if $\Delta H < 0$ (energetically favourable) and $\Delta S > 0$ (entropically favourable), reaction is always spontaneous regardless of temperature [or do the math using signs of $\Delta G = \Delta H - T\Delta S$]

14 Which of the following processes is always endothermic?

A dimerisation of $AlCl_3$

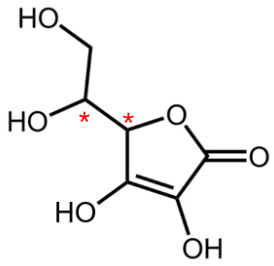
B melting of iron bar

C neutralisation between aqueous acid and aqueous alkali

D condensation of water

Bond / IMF formation releases energy and is exothermic.
Bond breaking / overcoming IMF requires energy and is endothermic.

15 How many chiral carbon atoms are present in a molecule of vitamin C?



vitamin C

A 1 **B** 2 **C** 3 **D** 4

Chiral C atoms must have 4 different groups bonded to it.
Refer to asterisks above.

END OF SECTION A

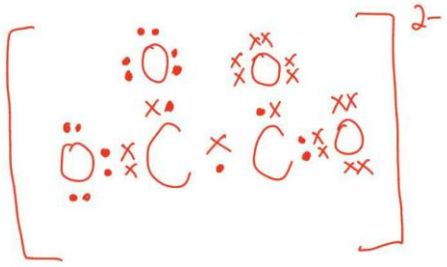
Section B – Structured Questions

Answer all questions.

1 Magnesium ethanedioate, MgC_2O_4, is an ionic solid present in mineral supplements to treat magnesium deficiency.

(a) (i) Given that there is a plane of symmetry in the structure of ethanedioate ion, draw a 'dot-and-cross' diagram to illustrate the bonding in ethanedioate ion.

Hence state the shape about each carbon atom.



Shape: ; trigonal planar ; [2]

Examiners' Comments:

- Many students did not read carefully / could not recognise that as MgC_2O_4 is an ionic solid, it would be composed of Mg^{2+} and $C_2O_4^{2-}$ ions. The question is asking only for the ethanedioate ($C_2O_4^{2-}$) ion. Students can link the naming of this ion to their OC nomenclature, ethanedioic acid (HOOCCOOH).
- Many students are still not counting their electrons properly, with many instances of incorrect valence electrons and/or not fulfilling octet rule. Many students also forgot the lone pairs on O atoms.
- A couple of students confused "plane of symmetry" with "mirror plane", and they mean different things. We draw a mirror plane when we want to draw the structure of the counterpart enantiomer; on the other hand, each individual enantiomer is said to have an absence of a plane of symmetry due to the chiral C. Note that there is no chiral C in this question.

(ii) Ethanedioate ion reacts with hydrochloric acid in a mole ratio of 1 : 1 in an acid-base reaction.

Explain why ethanedioate ion can be described as a Brønsted-Lowry base in this reaction and state the formula of its conjugate acid.

It accepts a proton from HCl ;

Conjugate acid: $HC_2O_4^-$; [2]

Examiners' Comments:

- Some students confused the definition with that of Lewis base.
- Many students did not recognise that each conjugate acid-base pair differs by exactly 1 H^+, giving $H_2C_2O_4$ as the answer.
- A significant number of students forgot about the charge on the conjugate acid.

Hydrated salt of magnesium ethanedioate has the formula $MgC_2O_4 \cdot xH_2O$, where x is an integer.

When 7.415 g of hydrated magnesium ethanedioate is heated strongly, it decomposes to form a white alkaline solid **P** and three gases **Q**, **R** and $H_2O(g)$. The molecular mass of **P** is 40.3 g mol^{-1}.

When the gases are passed through anhydrous calcium chloride, $H_2O(g)$ is completely absorbed and the mass of the calcium chloride increases by 1.800 g.

When the remaining gases, **Q** and **R**, are subsequently passed through aqueous potassium hydroxide, only **Q** reacts with potassium hydroxide.

Gas **R** is a poisonous gas. It reacts with oxygen gas to give gas **Q**.

(b) Suggest the chemical formula of **P**, **Q** and **R** respectively.

P: MgO **Q**: CO_2 **R**: CO [2]

all correct [2m] 2 correct [1m]

Examiners' Comments:

- Many students wrote "Mg" for **P**, missing the hint that the "alkaline solid" should be a metal oxide (recall from O-Levels that metal oxides are basic, non-metal oxides are acidic). Also, question gave that its M_r is 40.3.

(c) Hence write a balanced chemical equation for the decomposition of $MgC_2O_4 \cdot xH_2O$.

You may use x to balance the equation.

$MgC_2O_4 \cdot xH_2O \rightarrow MgO + xH_2O + CO_2 + CO$ [1]

Examiners' Comments:

- Some students added O_2 to the reactants, but the reaction is a decomposition and not a combustion.

(d) Determine the value of x in $MgC_2O_4 \cdot xH_2O$, showing your working clearly.

amount of $H_2O = \frac{1.800}{18} = 0.100$ mol ;

$$\frac{\text{amount of water}}{\text{amount of hydrated magnesium ethanedioate}} = \frac{x}{1} = \frac{0.100}{\left(\frac{7.415}{24.3+24+64+18x}\right)};$$

$$x = \frac{0.100}{\left(\frac{7.415}{112.3 + 18x}\right)}$$

$$7.415\,x = 0.100(112.3 + 18x)$$

$$5.615\,x = 11.23$$

$$x = 2 \ ;$$

Examiners' Comments:

- Many students conveniently omitted the x in M_r of the hydrated salt
- Some students did not recognise that x has to be an integer (i.e. cannot be decimal/fraction).

[3]

[Total: 10]

2 A methane fuel cell converts the chemical energy of methane and oxygen into electricity.

Figure 2.1 shows a simplified diagram of a methane fuel cell.

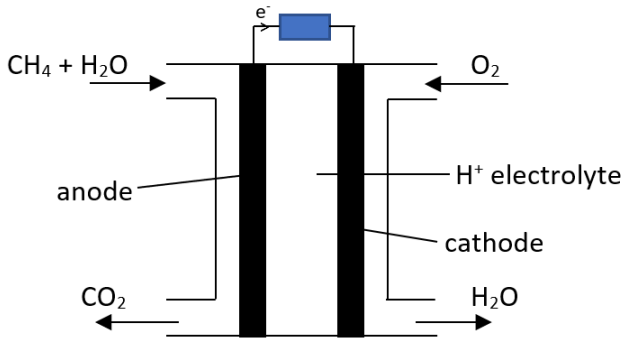


Figure 2.1

In the fuel cell where the electrolyte is an acid, methane is oxidised to carbon dioxide while oxygen gas in air is reduced to water.

(a) By determining the oxidation number of carbon atom in methane and carbon dioxide respectively, explain why the production of carbon dioxide from methane is an oxidation reaction.

C is oxidised from -4 in methane to +4 in CO_2. Since its oxidation number increases, it undergoes oxidation. ; [1]

Examiner's comments:
Generally well answered. A small number of students stated the OS of C in CH_4 is 0. Some students also did not explicitly state that there is an **increase** in the oxidation number.

(b) Write the half equation for the oxidation of methane.

$CH_4 + 2H_2O \rightarrow CO_2 + 8H^+ + 8e^-$ [1]

Examiner's comments:
Quite a number of students did not balance the H atoms, resulting in an equation that is not balanced.

(c) Using your answer in **(b)** and a relevant half equation obtained from the *Data Booklet*, write a balanced equation for the reaction taking place in the fuel cell.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ [1]

Examiner's comments:
Generally well answered if the answer in (b) is correct.

(d) Using bond energy values from the *Data Booklet*, calculate the enthalpy change for the reaction represented in **(c).**

Bonds broken: Bonds formed:

4 × C-H = 4 × 410 2 × C=O = 2 × 805

2 × O=O = 2 × 496 4 × O-H = 4 × 460 ;

$\Delta H = (4 \times 410 + 2 \times 496) - (2 \times 805 + 4 \times 460) = -818$ kJ mol^{-1} ;

[2]

Examiner's comments:
Common mistakes include using product – reactant, or using the wrong bond energy for C=O and O=O, or miscalculated the number of C=O bonds in CO_2 or O-H bonds in H_2O

(e) The actual value for the standard enthalpy change of the reaction in **(c)** is likely to be different from your answer in **(d)**.

Suggest two reasons why there is a discrepancy between the actual value and the value calculated in **(d)**.

Bond energy values from the data booklet are average values. ;

The enthalpy change of vaporisation of water was not taken into consideration in the calculation in (d). ;

[2]

Examiner's comments:
Common mistakes include stating that heat is lost to the surrounding, or that the heat capacity of the calorimeter was not taken into consideration. Some also stated that the bond energy values are 'estimates' instead of 'average value'.

(f) Given that the standard entropy change of the reaction in **(c)** is –241 J K^{-1} mol^{-1}, use your answer in **(d)** to calculate the maximum temperature at which the reaction would be spontaneous.

$\Delta G = \Delta H - T\Delta S$

For reaction to be spontaneous $\Delta G < 0$

$\Delta H - T\Delta S < 0$

$-818 - T(-0.241) < 0$;

$-818 < -0.241T$

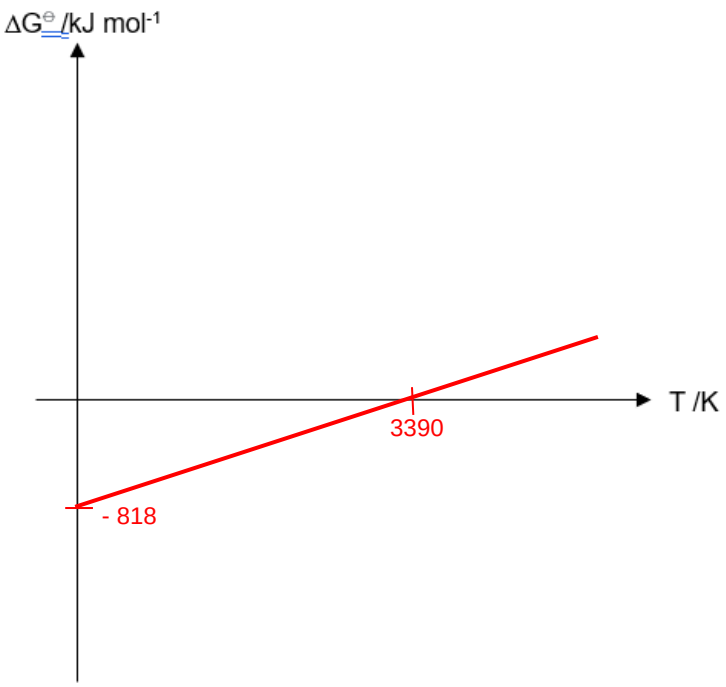
$0.241\ T < 818$

$T < 3390$ K ;

[2]

Examiner's comments:
Poorly answered. Many students forgot to change the units of ΔS to kJ mol^{-1} K^{-1}.

(g) Hence on the axes below, sketch a graph of $\Delta G^{\ominus}$, in kJ mol^{-1}, against T, in K. In your sketch, show clearly the values of the x-intercept and y-intercept, and suggest the value of the gradient.



Gradient: ..... 0.241 kJ mol^{-1} K^{-1} ; straight line ; x and y intercept ; [3]

[Total: 12]

Examiner's comments:

Poorly answered. Most students were not able to appreciate the mathematical relationship between the equation ' $\Delta G = \Delta H - T\Delta S$' to the graphical representation of y = mx + c.

3 (a) **Figure 3.1** shows the first ionisation energies of the elements sodium to potassium.

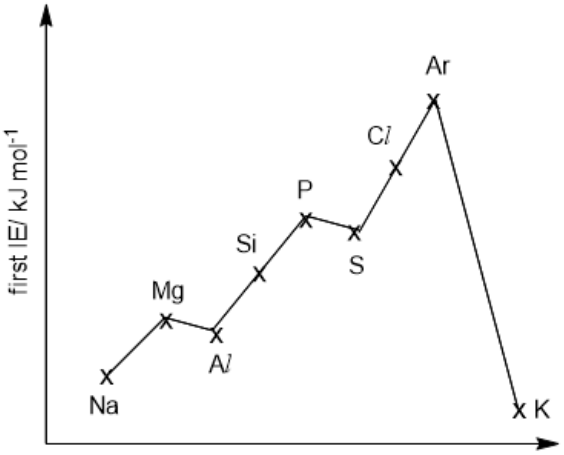


Figure 3.1

For each of the pairs of elements listed below, explain the difference between the values of their first ionisation energies.

(i) Na and K

Down the group, since **both nuclear charge and shielding effect increases**, the effective nuclear charge does not change significantly. ; With increasing principal quantum shell, the **distance** between the valence electron and the nucleus **increases**, the **electrostatic force of attraction** between the positive nucleus and the outermost electron **decreases** hence requiring **less energy to remove** the valence electrons. ; [2]

Examiner's comments:
A lot of students simply attributed to electrons further from nucleus due to more shells with some adding on increasing shielding effect.
Note that shielding effect increases with more shells of electrons, but this is offset by the increase in nuclear charge and hence effective nuclear charge does not change much.
Also, students must link the reason to electrons being attracted less strongly to nucleus and hence conclude that less energy is needed to remove valence electrons.

(ii) Mg and Al

Less energy is required to remove an electron from the **3p orbital in Al** than to remove an electron from the **3s orbital in Mg** ;
as the **3p electron is further away from the nucleus** and experiences **greater shielding** than the 3s electron. ; [2]

Examiner's comments:
It is an anomaly for the dip in first IE for Al.
Is a good habit to write the valence shell electronic configuration $3s^2$ for Mg and $3s^23p^1$ for Al to be clear which electrons are compared.
Some students attributed the greater shielding to the presence of more electrons which is not correct. The additional shielding comes from the 3s electrons from the 3s orbitals.

(iii) P and S

Inter-electron repulsion between the paired electrons in one of the **3p orbital** of S makes it easier for an electron to be removed from S than from P. ;

Hence **less energy** is required to remove an electron from the paired 3p electrons in S. ; [2]

Examiner's comments:
Most students are able to recognise it is due to interelectronic repulsion but were not clear in their explanation how this arises. Some use wrong terms like bonded electrons or lone pair electrons. Note that the interelectronic repulsion does not come about just because there are more electrons in the p orbitals.

(b) Table 3.1 shows the properties of aluminium and silicon.

Table 3.1

element	aluminium	silicon
melting point / °C	660	1414
electrical conductivity	very good	low

(i) State the type of structure aluminium has and explain why it is able to conduct electricity.

Giant metallic structure ;

It has **mobile electrons** to act as **charge carriers** ;

[2]

Examiner's comments:
Poor answers include confusion with giant ionic lattice structure and mobile ions as charge carriers.

(ii) State the type of structure of silicon explain why it has a high melting point.

Giant molecular/covalent structure ;

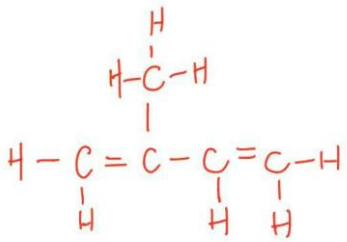
Si atoms are held by **strong/extensive covalent bonds** (electrostatic forces of attraction between shared pair of electrons (bonding electrons) and nuclei) which requires a **large amount of energy** to **break/overcome** ; [2]

[Total: 10]

Examiner's comments:
Many students did not recognise that Si has a diamond like structure and hence a giant covalent or giant molecular structure. During melting, it is these covalent bonds in the extensive structure that has to be overcome.

4 Isoprene is a hydrocarbon with the IUPAC name 2-methylbuta-1,3-diene. It is a colourless liquid under standard conditions.

(a) Draw the **displayed** formula of isoprene.



[1]

Examiner's comments:
Displayed formula ≡ **full** structural formula. Hence, need to show how the atoms are bonded, many gave CH_3 not shown in full.

(b) State and explain whether isoprene displays *cis-trans* isomerism.

No, isoprene does not display cis-trans isomerism ;

It does not have 2 **different groups** attached to **each of the C atoms** having the **C=C**

double bond / 2 same H atoms are bonded to each of the C atoms of C=C .

[2]

Examiner's comments:
Poorly explained. Wrong answers include using terms like functional groups and some ambiguous answers like H atoms on the same side of the C atoms / structure / molecule.

(c) Penta-1,3-diene is a constitutional isomer of isoprene. **Table 4.1** shows the boiling points of penta-1,3-diene and isoprene.

Table 4.1

compound	boiling point /°C
penta-1,3-diene	42.0
isoprene	34.1

Explain why isoprene has a lower boiling point compared to penta-1,3-diene.

Both have **simple molecular structures**;

Isoprene is **more spherical in shape/branched** and has **smaller surface area of**

contact hence **less energy** is required to overcome the **less extensive instantaneous**

dipole-induced dipole interactions between isoprene molecules ;

[2]

Examiner's comments:
Poorly done. Many did not realise that the two molecules are isomers with the same number of C atoms, that is, they have the same size.
Some ambiguous answers include penta-1-3-diene being longer or has a longer straight chain.
Some think that covalent bonds are broken during boiling!

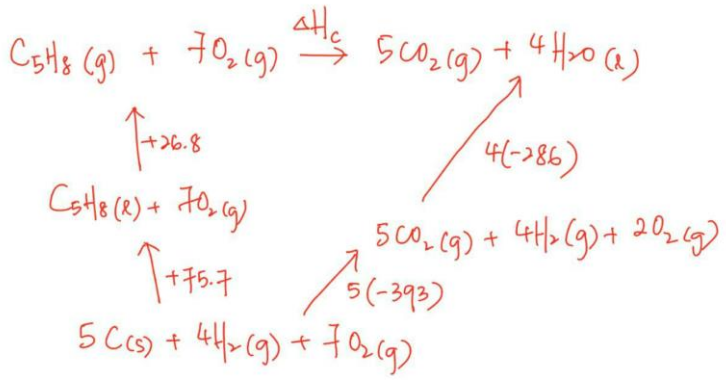
(d) The molecular formula of isoprene is C_5H_8.

Using data given in **Table 4.2**, construct an energy cycle to calculate the enthalpy change of the following reaction.

$$C_5H_8(g) + 7O_2(g) \rightarrow 5CO_2(g) + 4H_2O(l) \qquad \Delta H_{rxn}$$

Table 4.2

standard enthalpy change of vaporisation of isoprene /kJ mol^{-1}	+26.8
standard enthalpy change of formation of isoprene /kJ mol^{-1}	+75.7
standard enthalpy change of combustion of carbon /kJ mol^{-1}	-393
standard enthalpy change of formation of water /kJ mol^{-1}	-286



;;

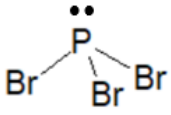
ΔH_c = – 26.8 – 75.7 + 5(–393) + 4(–286) = –3211.5 = **–3210 kJ mol^{-1}** (3sf);

[3]

[Total: 8]

Examiner's comments:
Poorly attempted.
Students should not combine steps but show each step clearly in an energy cycle. Each step also needs to be balanced accordingly (esp the mole of O_2) with state symbols for all species involved. Many also missed out the vaporisation of isoprene which is when isoprene changes from liquid to gaseous states.

5 PBr_3 is a discrete molecule with the following structure.



(a) Predict the bond angles about the central atoms of PBr_3, $SiCl_4$ and H_2S.

Hence using VSEPR theory, explain why the bond angle about the central atom of these compounds are different.

PBr_3: 107° $SiCl_4$: 109° H_2S: 105° ;

Electron pairs arrange themselves in such a way that repulsion is minimised.

Lone pair- lone pair repulsion > lone pair – bond pair repulsion > bond pair – bond pair repulsion ;

All three have 4 electron pairs but since H_2S has 2 lone pairs, PBr_3 has 1 lone pair and $SiCl_4$ has 0 lone pair, H_2S experiences greatest repulsion resulting in a smaller angle between the bond pairs. ; [3]

Examiner's comments:

Common mistake:

1. Bond angle in $SiCl_4$ is greatest, because it has the greatest electron pair repulsion (wrong concept!!).
   It should be: Bond angle in $SiCl_4$ is greatest, because it has the least electron pair repulsion.

2. No. of bond-pair electrons and lone-pair electron in each molecule should be stated clearly. Unless you have mentioned, the total no. of electron domains in each molecule.
   e.g. $SiCl_4$, has 4 electron domains around Si (central atom), it has 2 bond pairs (it's alright to not state the no. of lone pair electrons is zero).
   Or
   $SiCl_4$, has 4 bond pairs and 0 lone pairs (if the total no. of electron pairs around Si is not stated).

Pointers to answer such a question: 3 main points to take note of:

1. State the total no. of electron domains for the different compounds.
2. State the relative extent of repulsion between the different types of pairs of electrons, i.e. strength of electron pair repulsion:
   lone pair-lone pair > bond pair-lone pair > bond pair-bond pair.
3. State the no. of bond-pair and lone-pair of electrons for each of the compound (even if there is no lone pair electrons or all are bond pair electrons, you should state it clearly, unless in point 1, you've mentioned the total no. of electron domain in each compound).

(b) Element **D** forms an oxide with the formula **D**O_3.

The electronegativity values of **D** and other elements are given in Table 5.1.

Table 5.1

Element	Electronegativity Pauling Scale
P	2.19
Br	2.96
D	2.75
O	3.44

Using the above values, calculate the electronegativity difference between P and Br, and **D** and O. Hence, predict the structure and bonding present in **D**O_3.

EN difference between P and Br = 2.96 – 2.19 = 0.77

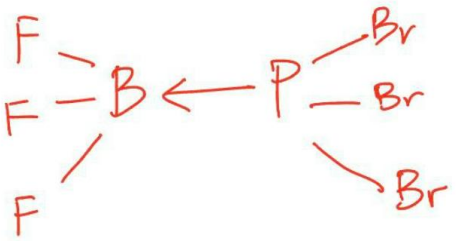
EN difference between **D** and O = 3.44 – 2.75 = 0.69 ;

Since the EN difference between **D** and O is smaller than that between P and Br, it is more covalent than P-Br, hence **D**O_3 has a simple molecular structure ; held by strong electrostatic forces of attraction between shared pair of electrons and nuclei. ;

[3]

(c) PBr_3 reacts with BF_3 to form an adduct $PBr_3 \cdot BF_3$.

Draw the structure of the adduct formed. State the type of bond formed and explain how it is formed.



;

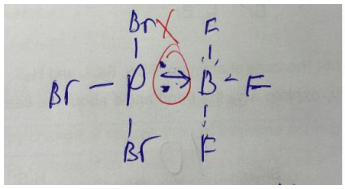
B in BF_3 has an energetically accessible vacant orbital which can take in a lone pair from P of PBr_3 ;

forming a dative bond ;

[3]

Examiner's comments:

1. The following drawing is not accepted: do not draw the arrow showing lone pair electrons from P atom to B atom and at the same time, drawing the lone pair of electrons.



2. Inappropriate description for the dative bond formed between P (phosphorous) and B (boron) atoms.:
   x "The lone pair of electrons on P atom in PBr_3 is donated to B atom in BF_3 molecule".
   √ ["The lone pair of electrons on P atom is shared with B atom in BF_3 to form a dative covalent bond].

[Total: 9]

6 Helium is used to fill party balloons.

A 60.0 dm^3 industrial tank of helium gas at 25 °C and 125 atm was used to fill up some balloons.

After some balloons were filled, the pressure in the tank decreased to 45 atm.

(a) Calculate the amount of helium gas present in the industrial tank initially.

$pV = nRT$

$(125 \times 101325) \times (60 \div 1000) = n \times 8.31 \times (25 + 273)$

$n = 306.87 = 307$ mol ;

[1]

Examiner's comments:
- ignorant of the units used in the ideal gas equation, PV = nRT:
  P: Pa (Pascal) ; V: m^3; R: J mol^{-1} K^{-1}; T: K)
- common mistakes are in the unit conversion. Ignorant of the following units conversion:
  1 dm^3 = 10^{-3} m^3; 1atm = 101325 Pa (found in the Data Booklet)

(b) Determine the amount of helium gas used to fill up the balloons, assuming the temperature is constant.

$\frac{P_1}{n_1} = \frac{P_2}{n_2}$

$\frac{125}{306.87} = \frac{45}{n_2}$;

$n_2 = 110.47$

amount used = 306.87 – 110.47 = 196.4 = 196 mol ;

Volume of the gas in the tanks, remains the same, though the pressure changes:

At P_1 = 125 atm: $V_1 = \frac{n_1 RT}{P1}$; At P_2 = 45 atm: $V_2 = \frac{n_2 RT}{P_2}$

At both pressures, P_1 and P_2, volume of gas are the same:

$\therefore V_1 = V_2 \Rightarrow \frac{n_1 RT}{P1} = \frac{n_2 RT}{P_2}$ $\frac{n_1}{P1} = \frac{n_2}{P_2}$

alternative method:

PV = nRT

$(125\text{-}45) \times 101325 \times \frac{60}{1000} = n \times 8.31 \times (25+273)$

n = 196 mol (no. of mol of helium gas used to fill all the balloons.

Volume of gas that is used to fill the balloons

[2]

(c) Assuming each balloon has a volume of 4 dm^3 and an internal pressure of 1.2 atm, calculate the maximum number of balloons, in whole number, that can be filled with a 60.0 dm^3 industrial tank of helium gas at 25 °C and 125 atm.

Assume that the temperature is constant.

$P_{tank}V_{tank} = P_{balloon}V_{balloon} \times$ number of balloons

$(125)(60) = (1.2)(4) \times$ number of balloons ;

number of balloons = 1562.5

maximum number of balloons = 1562 ;

[2]

(d) State and briefly explain if helium gas behaves more ideally in the tank, or when present in balloons at the same temperature.

Helium gas behaves more ideally in the balloon
.....
as gases behave more ideally at lower pressures. ;
.....
Or
..... [1]
the gases have weaker intermolecular molecular forces or weaker instantaneous dipole-

induced dipole interaction between the gas. atoms/particles ;

Examiners' Comments:

Many gave the wrong answer as "gas in the tank behaves ideally",
The reason given for this answer, majority gave either one of the following incorrect reasons:
(a) "because the tank has a larger volume".
without due consideration for the much higher pressure in the tank stated specifically in the question.
With a larger pressure in the tank, the intermolecular forces among the gas particles will be significant, which will give rise to non-ideal behaviour of the gas.
(b) "because the pressure is higher in the tank".
completely had no idea the factors for ideal gas behaviour is under low pressure and high temperature.

[Total: 6]

END OF SECTION B