HWA CHONG INSTITUTION
2022 C1 H2 CHEMISTRY PROMOTIONAL EXAM
MARK SCHEME & TEACHING SOLUTIONS

Paper 1

1	2	3	4	5	6	7	8	9	10
C	A	B	A	D	A	D	B	D	D
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
C	D	C	B	C	A	C	A	B	C

Comments

1 **C** Obtain the proton number based on the identity of the element in the Data Booklet. Calculate the no. of neutrons by taking mass number (indicated as superscript on the element) minus proton number:

A	No. of protons = **2**; no. of neutrons = 2 – 2 = **0**
B	No. of protons = **4**; no. of neutrons = 8 – 4 = **4**
C	No. of protons = **20**; no. of neutrons = 40 – 20 = **20**
D	No. of protons = **82**; no. of neutrons = 210 – 82 = **128**

Only ^{40}Ca has both numbers matching the given nuclear magic numbers.

2 **A**

1	Each nitrogen atom in cyanogen has one lone pair of electrons, hence statement is correct.
2	Both carbon atoms in cyanogen are sp hybridized – there are two electron groups around each carbon atom and the shape around each carbon is linear, hence statement is correct.
3	There should be three σ bonds: C–N, C–N and C–C, hence statement is incorrect.

3 **B**

A	The zig-zag chains are flat and unlikely to form regular 3D spaces in the lattice structure like the tetrahedral 3D arrangement for ice, hence statement is incorrect.
B	Each hydrogen bond in HF is stronger than that in H_2O since F is more electronegative than O, and hence draw away more electron density from H atom, resulting in a greater partial positive charge on H so attraction between the H and the lone pair of another HF molecule is stronger. Statement is correct.

C	The question states that the bond angle around F atom is similar to that around O in ice, hence bond angle around each F atom should be 104.5°. Statement is incorrect.
D	Solid HF exists as discrete HF molecules held together by intermolecular hydrogen bonding. It is still a simple molecular structure, not giant covalent. Statement is incorrect.

4 **A**

1	More gas added into a flask of fixed volume, hence total pressure in the flask will increase. Or consider $PV = nRT$, where n increases and V is constant, so P will increase. Statement is correct.
2	Mole fraction of a gas in a mixture is "no. of moles of that gas / total no. of moles of gas", since total moles of gas has increased, the mole fraction of each gas will decrease. Statement is correct.
3	Partial pressure of each gas is defined as the pressure that each gas exerts on the flask as though it is alone in the flask. Since the no. of moles of N_2 and O_2 did not change and the volume of the flask did not change, their partial pressures will be unchanged. Or consider partial pressure = mole fraction × total pressure = $(n_{gas} / n_{total}) \times P_{total}$. P_{total}/n_{total} is a constant (use $PV = nRT$), so if n_{gas} remain the same, partial pressure of that gas remains the same.

5 **D** The **empirical formula** of a compound is the **simplest formula** which shows the **ratio** of the **atoms** of the different elements in the compound.

The **molecular formula** of a compound is the **formula** which shows the **actual number** of **atoms** of each element in one molecule of the compound.

1	$\text{NaC}l$ is an ionic compound and hence it does not have a molecular formula. Ionic compound formulae are always empirical formula since the actual number of ions is a very large number and it is the simplest ratio of atoms that is reflected in an ionic formula.
2	Water is a simple molecular compound that comprise 2 H atoms and 1 O atom, which means that its formula is both the empirical formula and molecular formula.
3	Propene is a simple molecular compound that comprise 3 C atoms and 6 H atoms, hence its molecular formula is C_3H_6. The simplest ratio of atom would be CH_2 which is the empirical formula.

6 **A** Calculate the number of moles of particles for each option and compare them. The option with the lowest number of moles of particles will give the smallest number of particles since 1 mole of particles contain Avogadro's number (6.02×10^{23}).

A	No. of moles of atoms in 15 g Fe = (15 ÷ 55.8) = 0.269 mol
B	No. of moles of ions in 50 g $NaCl$ = (50 ÷ 58.5) × 2 = 1.71 mol
C	No. of moles of molecules in 15 dm^3 of N_2 = (15 ÷ 24) = 0.625 mol
D	No. of moles of molecules in 10 cm^3 of C_6H_{14} = (10 × 6.55) ÷ 86.0 = 0.762 mol

7 **D**

1	The enthalpy change of formation refers to the energy change in forming a substance from its constituent elements (not atoms!) at their standard state. The correct representation of $\Delta H^{\ominus}_{\text{formation}}(NH_3)$ is: $\frac{1}{2} N_2(g) + 3/2\ H_2(g) \rightarrow NH_3(g)$
2	Bond energy refers to the energy required to break one mole of the covalent bond in the gaseous state, the equation is incorrect because it shows the breaking of only half a mole of the Br–Br bond. The correct representation of $\Delta H^{\ominus}_{\text{bond energy}}(\text{Br–Br})$ is: $Br_2(g) \rightarrow 2Br(g)$
3	Ionisation energy refers to energy required to remove one mole of electrons from one mole of the gaseous atoms. The equation is incorrect because Mg should be in the gaseous state. The correct representation of $\Delta H^{\ominus}_{\text{ionisation energy}}(Mg)$ is: $Mg(g) \rightarrow Mg^{+}(g) + e^{-}$

8 **B** $\Delta H_{\text{solution}}$ = – L.E. + sum of $\Delta H_{\text{hydration}}$ of the ions formed

$= -(-2195) + (-1577) + 2(-363) = -108\ \text{kJ mol}^{-1}$

9 **D**

A	At point A, entropy is zero, meaning the particles are at their maximum state of order (no disorder), hence statement is incorrect.
B	Between points C and D, the liquid water is increasing in temperature. It is not at equilibrium. Dynamic equilibrium between the solid and liquid states occurs at BC, while dynamic equilibrium between the liquid and gaseous states occurs at DE. Hence statement is incorrect.
C	At BC, the temperature remains constant so average kinetic energy does not change. Hence statement is incorrect.
D	At DE, the liquid state is converting to gaseous state while at BC the solid state is converting to liquid state. Gas particles have a greater disorder compared to liquid particles, so the increase in entropy in converting from liquid to gas is larger. Statement is correct.

10 **D** A catalyst does not change the initial and final energy levels of the reactants and products, hence the enthalpy change of reaction does not change. This would rule out options B & C immediately.

Catalysis offers an alternative reaction pathway that has a lower activation energy. This means that option A is wrong. This leaves option D as the answer as the diagram shows that the enthalpy change of reaction is unchanged while the activation energy is clearly lower for the catalyzed reaction pathway.

11 **C**

^{242}Cm	4	$\xrightarrow{\text{160 days}}$	2	$\xrightarrow{\text{160 days}}$	1	$\xrightarrow{\text{160 days}}$	½	$\xrightarrow{\text{160 days}}$	¼
^{248}Bk	1	$\xrightarrow{\text{320 days}}$			½	$\xrightarrow{\text{320 days}}$			¼

From the table below, it takes ^{242}Cm 4 half-lives (160 × 4 = 640 days) to go from 4 to ¼, while it takes ^{248}Bk 2 half-lives (320 × 2 = 640 days) to go from 1 to ¼.

Hence at the end of 640 days, the ratio of ^{242}Cm : ^{248}Bk = ¼ : ¼ which gives a 1 : 1 ratio.

12 **D**

1	Comparing Expts 1 & 2, [CH_2ICH_2I] and [I_2] remain constant, but the light intensity increases by 4× while the rate increase by 2×. Hence the rate is proportional to $\sqrt{\text{light intensity}}$.
2	Comparing Expts 3 & 4, [CH_2ICH_2I] and light intensity remains constant but [I_2] increases by 2× while the rate remains constant. Hence the rate is independent of [I_2].
3	Comparing Expts 2 & 3, [CH_2ICH_2I] increases by 2× and the light intensity and [I_2] remain constant, while the rate increases by 2×. Hence the rate is directly proportional to [CH_2ICH_2I].

13 **C** This question tests understanding and application of Le Chatelier's principle – that a change imposed on a system at equilibrium cannot be completely offset by a shift in the position of equilibrium.

Hence when additional 0.5 mol of P was added, not all of it was reacted when the position of the equilibrium shifted right. Therefore [P] left should be more than 2.0 mol dm^{-3} (since some of the 0.5 mol of P added remained behind), and should not exceed 2.5 mol dm^{-3} (otherwise no reaction and shift in the position of the equilibrium would have occurred).

The decrease in the amount of Q should reflect the 2 : 1 stoichiometry in the chemical equation. Consequently, Q should decrease less than 0.25 mol since not all of the 0.5 mol of P reacted. This means that [Q] should be between 0 and 1 mol dm^{-3}.

Similarly, the increase in the amount of R should be less than 0.5 mol (since less than 0.5 mol of P reacted), and therefore [R] should be more than 2.0 mol dm^{-3} but less than 2.5 mol dm^{-3}.

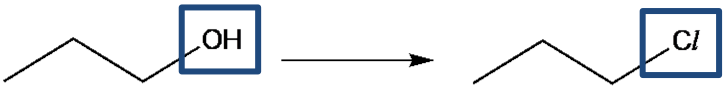
14 **B** The graph must be interpreted correctly in order to anaylse which of the options are correct.

The graph shows that the % of X increases (POE shifts to the right) as P increases. Hence an equilibrium reaction with fewer moles of gas on the RHS will fit this increase.

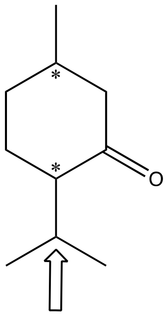
The graph also shows that the % of X decreases (POE shifts to the left) when the T increases from 298 K to 500 K. Hence an equilibrium reaction which is endothermic in the backward direction (exothermic in the forward reaction) will fit this decrease.

A	There are more number of moles of gas on the RHS, thus this reaction will not fit the changes described when T increases.
B	There are less number of moles of gas on the RHS and the reaction is exothermic. This reaction will fit the changes described when T increases.
C	Although there are less number of moles of gas on the RHS, the reaction is however endothermic. Thus, this reaction will not fit the changes described when T increases.
D	The number of moles of gas are the same on the RHS and LHS. The reaction is also endothermic. Thus, this reaction will not fit the changes described when T increases.

15 **C** It is important to understand the definitions for the types of reactions well to answer this question.

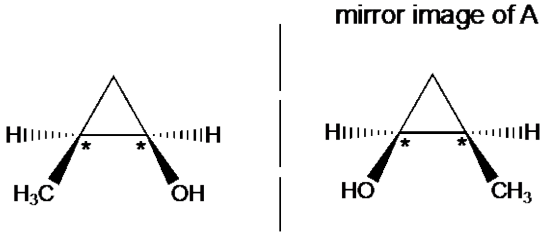
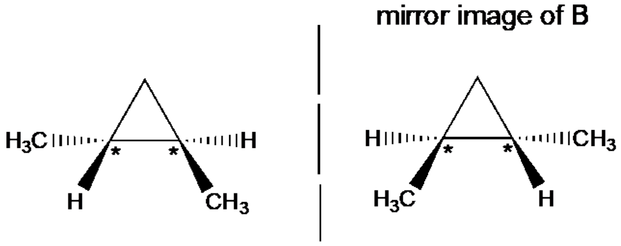
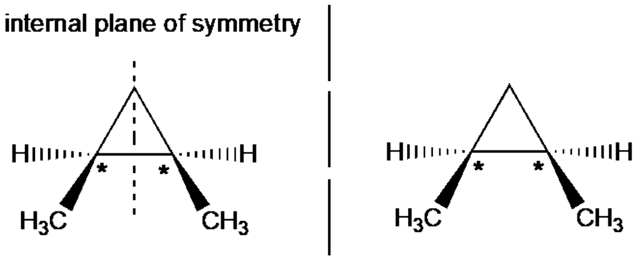
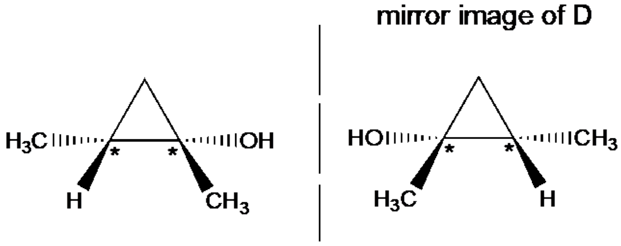
A	An addition reaction is when an organic molecule, usually containing a double bond (e.g. C=C) reacts with another molecule to give only one product. However, the chemical equation describes the 2-chloropropane becoming 1-propene, which means that HCl has been removed from the starting molecule. Thus the reaction is **elimination.** Option is incorrect.
B	The chemical equation describes an alcohol molecule and carboxylic acid molecule coming together to form a bigger molecule, an ester, with the elimination of water, an example of a small molecule. The product, an ester, does not contain a double bond that was formed after the removal of a small molecule. Thus type of reaction is **condensation**. Option is incorrect.
C	1-propene has been converted to propane. This means that hydrogen atoms have been added across the carbon-carbon double bond. Hence **reduction** has occurred. Option is correct.
D	Substitution is when one atom or group of atoms replaces another atom or group in a molecule. 

	For instance, if substitution were to occur, the –OH group is replaced by another group, e.g. Cl^-. However propan-1-ol has been converted to propanoic acid. This is the oxidation of a primary alcohol to a carboxylic acid (to be learnt in Topic 16 Hydroxy compounds). Alternatively, the oxidation of propan-1-ol can also deduced by the change in oxidation number of carbon. Oxidation number of C in $CH_3CH_2\underline{C}H_2OH$ changed from –1 to +3 in $CH_3\underline{C}OOH$. Hence **oxidation** occurred. Option is incorrect.

16	**A**	**1**	One important thing to note when reading skeletal structures is that hydrogen atoms are not shown, and that carbon always forms 4 bonds. Statement is correct.
		2	The number of stereoisomers of menthone depends on the number of chiral centres, or if any *cis-trans* isomers exist. Since there is no cis-trans isomerism in this molecule, the number of stereoisomers would be based on the number of enantiomers. This is based on the number of chiral centres in the molecule, and whether its mirror image is superimposable on itself. A chiral center is an atom with a tetrahedral geometry around it that is bonded to four different groups. There are only 2 chiral centres in menthone, indicated by the asterisk.  this is not a chiral centre This carbon is not a chiral centre as there are 2 identical methyl groups bonded to it. Hence the number of stereoisomers is $2^2 = 4$. Statement is correct.
		3	Due to oxygen being more electronegative than carbon, the electron density in the C=O bond will be attracted towards oxygen. Hence the carbon bonded to the oxygen thus carries a partial positive charge and is known as an electrophilic site. Statement is wrong.

17 **C** Molecules that are optically active contain chiral centre(s) and have non-superimposable mirror images. These 4 molecules contain chiral centres but the presence of chiral centres do not always mean that the molecule has a non-superimposable mirror image and hence optically active.

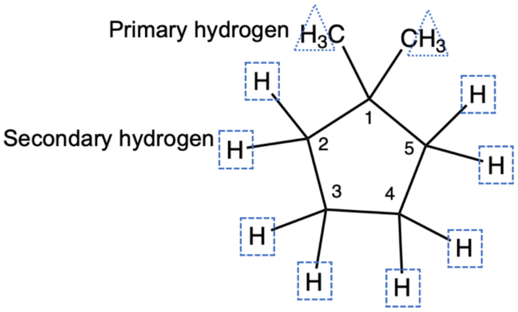
The presence of an internal plane of symmetry will mean that the molecule is identical (superimposable) to its mirror image and is optically inactive.

A	 There is no internal plane of symmetry in the molecule. Mirror image of A is non-superimposable on itself. It is optically active.
B	Same reasoning as **A**. 
C	There are 2 chiral centres in this molecule. However, an internal plane of symmetry is present. The mirror image of the molecule is superimposable on itself and hence the molecule is optically inactive (achiral compound, also known as a meso compound). 
D	Same reasoning as **A**. 

18 **A** Methane and chlorine react together in the presence of ultraviolet light in a process known as free radical substitution (FRS).

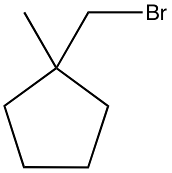
1	For hydrogen gas to be produced during FRS, 2 hydrogen radicals need to collide in termination step. However the formation of hydrogen radicals is unlikely due to the strong C-H bond. Statement is incorrect.
2	Bond breaking occurs at every step in the mechanism for FRS. As a quick recap: Initiation: breaking of X−X bond to form halogen radicals. Propagation: breaking of C−H bond to form C−X bond. Termination: breaking of another X−X bond to form halogen radicals. Statement is incorrect.
3	The formation of CH_3Cl can happen in propagation step, or during the termination step. Propagation: $\bullet CH_3 + Cl_2 \downarrow CH_3Cl + Cl\bullet$ Termination: $Cl\bullet + \bullet CH_3 \downarrow CH_3Cl$ Statement is correct.

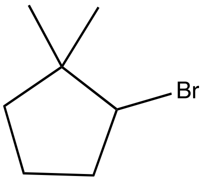
19 **B** To find out the possible mono-brominated products when 1,1–dimethylcyclopentane undergoes FRS, we have to know the position of all the hydrogen atoms.

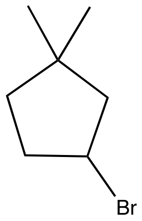


There are a total of 6 1° hydrogens and 8 2° hydrogens. Substitution of any of the above hydrogens will give a mono-brominated product. However, due to an internal plane of symmetry, the mono-substitution of hydrogen on carbon-2 or carbon-5 will give the same product. The case is similar for mono-substitution of hydrogen on carbon-3 or carbon-4, and the 2 primary hydrogens in the methyl groups on carbon-1.

Hence there will be a total of 3 different mono-substituted products.





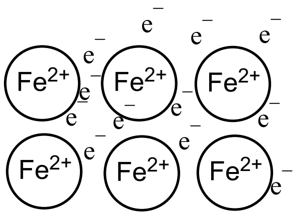


20 **C**

1	Carbon monoxide is oxidized to form carbon dioxide. Statement is incorrect.
2	NO and NO_x are reduced to form nitrogen gas. Statement is correct.
3	Unburnt hydrocarbons are oxidized to form carbon dioxide and water. Statement is correct.

Paper 2

1 (a)



[1] diagram

The metallic bonding **[0.5]** in iron is the electrostatic forces of attraction between the Fe^{2+} (accept Fe^{3+}) cations and the sea of delocalised electrons **[0.5]**.

(b) (i) Electronic configuration of Cu^+ is $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}$ **[1]**
Electronic configuration of Zn^+ is $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}\,4s^1$ **[1]**

(ii)
- Second IE of Cu involves removal of a 3d electron **[0.5]**. Second IE of Zn involves removal of a 4s electron **[0.5]**.
- The 3d subshell is closer to the nucleus **[0.5]** than the 4s subshell. The electron to be removed from Cu experiences greater electrostatic attraction towards the nucleus **[0.5]**. Hence, more energy required to remove the 3d electron from Cu, resulting in greater second IE for Cu.

(c) (i) By Le Chatelier's principle, a low temperature favours the forward exothermic reaction, which results in a high yield of NH_3 **[1]**. However, at low temperatures, the rate of reaction is too slow to be economical **[1]**.
OR
By Le Chatelier's principle, a high temperature ensures the rate of reaction is high. **[1]** However, high temperature favours the backward endothermic reaction which results in a low yield of NH_3 **[1]**.

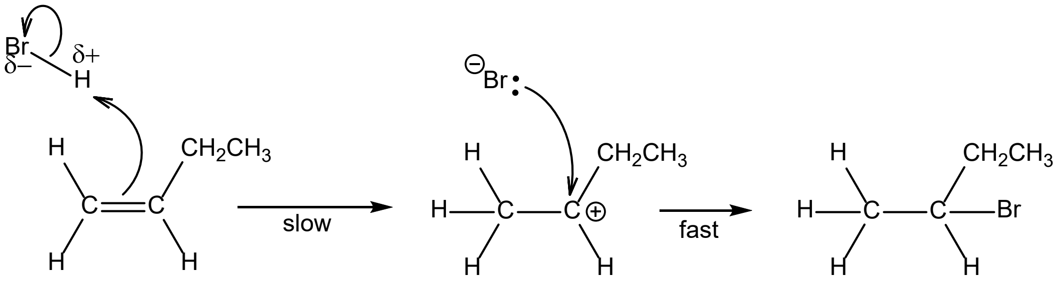
(ii) Amount of $NH_3(g) = \dfrac{3300 \times 1000 \times 1000}{14.0 + 3(1.0)} = 1.941 \times 10^8$ mol **[0.5]**

Amount of $N_2(g)$ required $= \dfrac{(1.941 \times 10^8)}{2} \times \dfrac{100}{15} = 6.471 \times 10^8$ mol **[1]**

Volume of $N_2(g)$ required $= (6.471 \times 10^8)(24.0\ dm^3)$
$= 1.553 \times 10^{10}\ dm^3$
$= \underline{1.55 \times 10^{10}\ dm^3}$ (to 3 sf) **[0.5]**

(iii) Volume of air required $= 1.553 \times 10^{10} \times \frac{100}{78.08} = \underline{1.99 \times 10^{10}\,dm^3}$ (to 3 s.f.) **[1]**

2 (a) (i) [1] Electrophilic addition



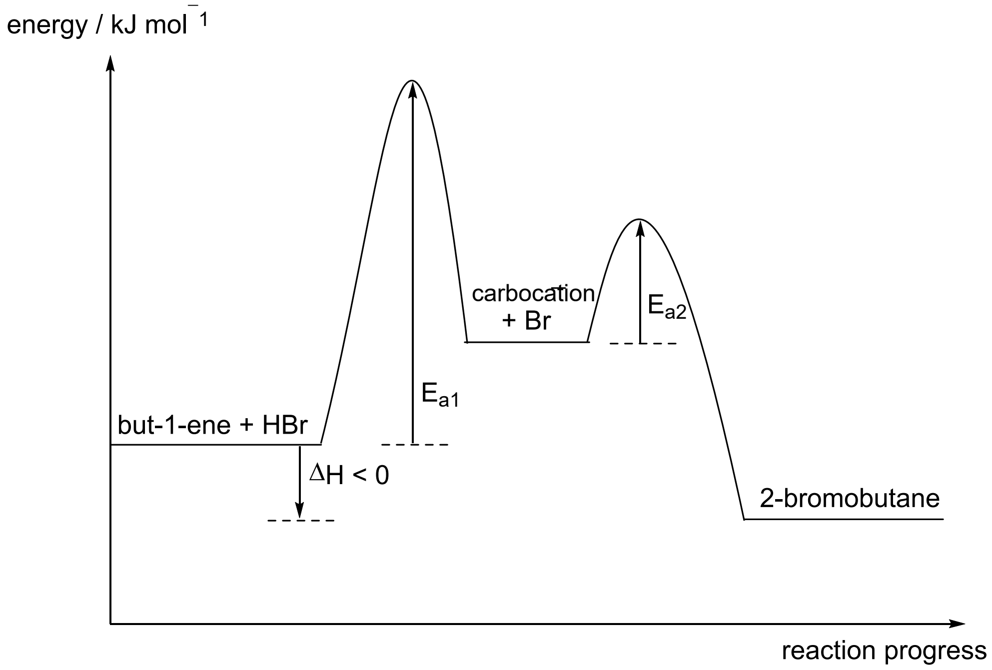
[1] for first step
[1] for second step

(ii) Bond energy is the energy required to break 1 mole of a covalent bond in the gaseous state. **[1]**

(iii) ΔH = BE(C=C) + BE(H—Br) − BE(C—C) – BE(C—H) − BE(C—Br)
= 610 + 366 – 350 – 410 – 280 **[1]**
= $-$ 64.0 kJ mol^{-1} **[1]**

(iv) The activation energy is the energy barrier the reactants must overcome in order to become the products. **[1]**

(v)



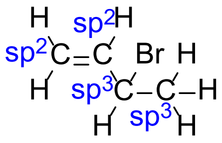
[0.5] label axes (also accepted reaction pathway / reaction coordinate for x-axis label)
[0.5] label E_{a1} and E_{a2} where $E_{a1} > E_{a2}$
[0.5] label ΔH with correct arrow direction
[0.5] label reactants (but-1-ene and HBr), intermediates (carbocation and Br^-) and product (2-bromobutane), number of atoms and charges must be balanced.

(vi) Formation of 2-bromobutane involves a more stable secondary carbocation **[1]**.

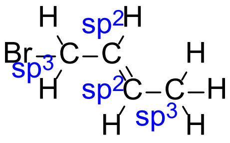
A secondary carbocation has one more inductively electron-donating alkyl group on the positively charged carbon than a primary carbocation which forms 1-bromobutane **[1]**.
OR
The carbocation which forms 2-bromobutane has two inductively electron-donating alkyl groups on the positively charged carbon compared to one in the carbocation which forms 1-bromobutane **[1]**.

(b) (i) The three adjacent carbon atoms (carbon-1, carbon-2 and carbon 3) each contains one unhybridised p orbital perpendicular to the plane of its sp^2 hybrid orbital. These three p orbitals **[0.5]** overlap side-on **[0.5]** to allow delocalisation of electrons.

(ii)



A



B

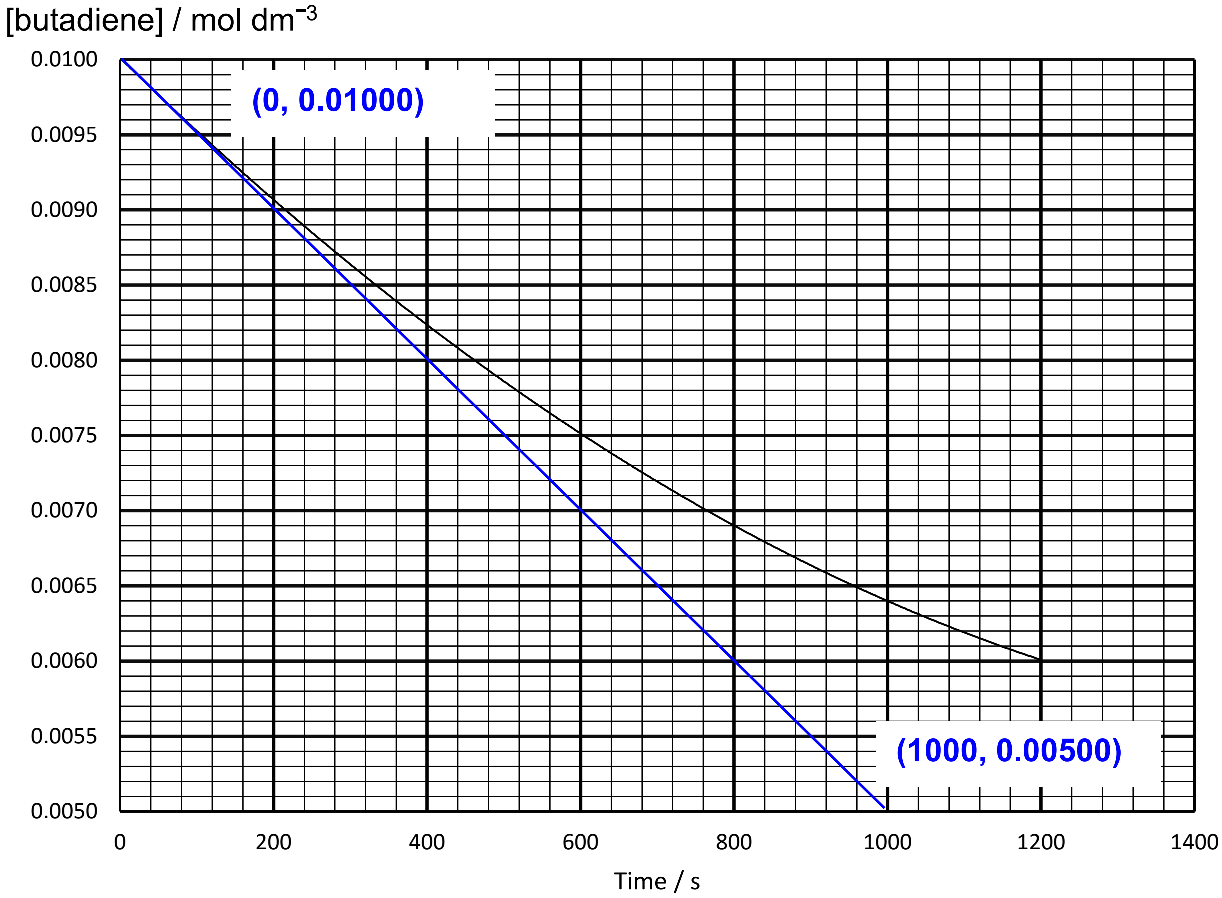
no. of $C(sp^2)$-$C(sp^2)$ bonds	1	1
no. of $C(sp^2)$-$C(sp^3)$ bonds	1	2
no. of $C(sp^3)$-$C(sp^3)$ bonds	1	0
	[0.5] for **A**	**[0.5]** for **B**

(iii) An sp^2 hybrid orbital has more s character / less p character than an sp^3 hybrid orbital. **[0.5]**

The effectiveness / degree of the overlap increases as follows: between two sp^3 orbitals < between a sp^2 and a sp^3 orbital < between two sp^2 orbitals. **[0.5]**

(iv) **B** is more stable as **B** has one stronger sp^2–sp^3 bond in place of an sp^3–sp^3 bond in **A**. **[1]**

(c) (i)



Initial rate = − gradient = $-\frac{y_1-y_2}{x_1-x_2} = -\frac{0.01-0.0050}{0-1000}$

$= 5.00 \times 10^{-6}$ mol dm^{-3} s^{-1}

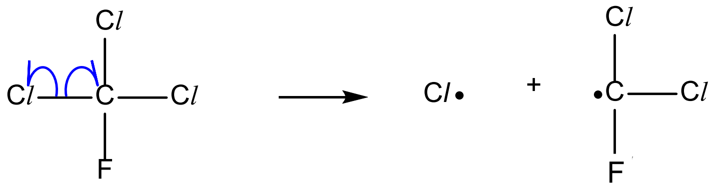
[1] tangent + working + final answer within **<u>range 4.5 × 10^{-6} to 5.5 × 10^{-6}</u>** mol dm^{-3} s^{-1}

(ii) $k = \frac{\text{rate}}{[\text{butadiene}]^2} = \frac{5.00 \times 10^{-6}}{(0.01)^2}$ = 0.0500 **[1]** mol^{-1} dm^3 s^{-1} **[1]**

3 (a) Condensation involves the formation of intermolecular forces which release energy. **[1]**

(b) They have low boiling points and can be easily liquefied by pressure a little above atmospheric pressure / They are chemically and biologically inert (and hence safe to use and handle). **[1]**

(c) (i)



[0.5] arrows **[0.5]** •CCl_2F + C*l*•

Type of bond breaking: <u>homolytic</u> fission **[1]**

(ii) step 1: $Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$ **[1]**

step 2: $ClO\bullet + O_3 \rightarrow 2O_2 + Cl\bullet$ **[1]**

(iii) Cl_2 / C*l*–OC*l* (or Cl_2O) **/** C*l*O–OC*l* (or Cl_2O_2) **[1]**

(iv) <u>C-F (and C-H) bond</u> in HFCs <u>is stronger than C-C*l* bond</u> in CFCs and will <u>not be broken</u> by UV light to form <u>F (and H) radicals</u>, hence no ozone depletion potential. **[1]**

(d) $q_2 = mc_{liq}\Delta T = (700 \times 2.24 \times 8) = 12544 = 12.5$ kJ **[1]**

No. of moles of propane = 700/44 = 15.9 mol
$q_3 = n\Delta H_{vap} = (15.9 \times 24500) = 389550 = 390$ kJ **[1]**

$q_1 = 12.5 + 390 + 78.3 = 481$ kJ **[1]**

Paper 3

1 (a) (i) Si: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$ **[1]**

(ii) Similarity (one of the following): **[1]**

- The 3s and 3p orbital both belong to the third principal quantum shell
- The 3s and 3p orbital can each hold a maximum of two electrons (of opposite spins)

Difference (one of the following): **[1]**

- The 3s orbital is spherical while the 3p orbital has a dumb-bell shape
- The 3s orbital is lower in energy than the 3p orbital

(iii) Difference (any one of the following): **[1]**

- The 3p orbital is higher in energy than the 2p orbital
- The 3p orbital is larger (in size) than the 2p orbital
- The 3p orbital belongs to the third quantum shell, while the 2p orbital belongs to the second quantum shell

(b) (i)

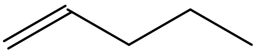
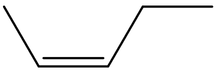
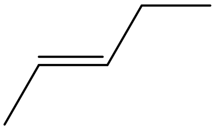
	Ca	Mg	Si	O
%	18.51	11.22	25.95	44.32
A_r	40.1	24.3	28.1	16.0
No. of moles in 100 g	0.4616	0.4617	0.9235	2.77
Ratio	1	1	2	6

Hence, empirical formula is $CaMgSi_2O_6$

[1] correct working shown
[1] correct answer

(ii) SiO_3^{2-} **[1]**

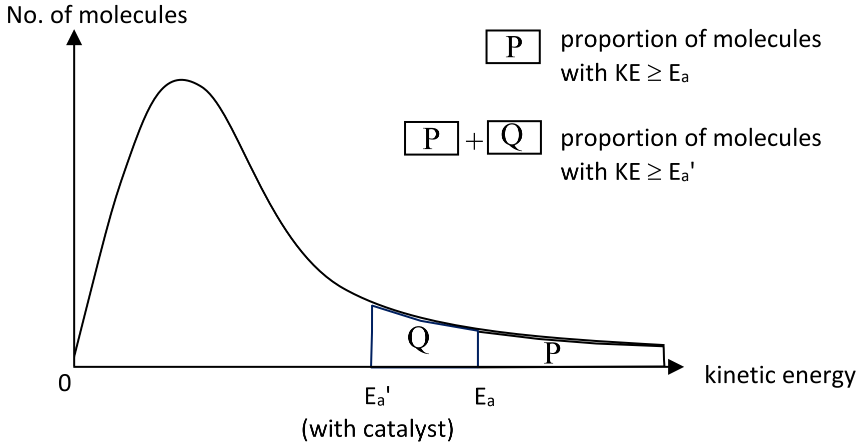
(c) (i)

D	E and F	
 pent-1-ene	 *cis*-pent-2-ene	 *trans*-pent-2-ene

[0.5] each correctly drawn structure
[0.5] each name corresponding to correct structure

(ii) Cis-trans isomerism exists between E and F. It arises because there is restricted rotation around the C=C double bond in molecules E and F **[1]** and there are non-identical groups on each carbon in the bond with restricted rotation (i.e. the C=C bond). **[1]**

(iii)



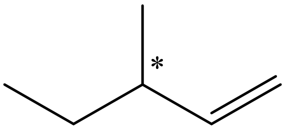
The catalyst provides an alternative reaction pathway of lower activation energy (E_a') compared to the uncatalysed reaction (E_a). **[1]**

The proportion/fraction of (reactant) particles that have KE ≥ activation energy hence increases from area P to area P+Q, leading to increased frequency of effective collisions, **[1]** hence rate of reaction increases even without an increase in initial concentrations of reactants. Hence, rate constant (k) must have increased **[1]** (since Rate = $k[A]^x[B]^y$).

(iv) At low pressures, concentration/partial pressures of reactants are low, there are many active sites available on the catalyst. As the concentration/partial pressures of reactants increase, more reactants can be adsorbed onto active sites. Hence, rate of reaction increases proportionately to the increase in each reactants concentration/pressure (first order). **[1]**

At higher pressures, the active sites on the catalyst are saturated. Products must desorb from the active sites before new reactants can be adsorbed. Increasing the concentration/partial pressure of the reactants thus has no effect on the rate (zero order). **[1]**

(d) G:



[1]

(e) (i) Since pressure and amount of each species is constant during cooling

$$\frac{V_1}{T_1}=\frac{V_2}{T_2}$$

Thus, volume of carbon dioxide at 150 °C can be found:

$V_{(CO2)} = \frac{V_2}{T_2} \times T_1 = \frac{48.5}{(20+273)} \times (150 + 273) =$ $\underline{70.0\ cm^3}$ **[1]**

(ii) $\frac{x}{1}=\frac{70}{10} \Rightarrow x = 7$

$\therefore \frac{x+{}^{y}/_{4}}{1}=\frac{95}{10} \Rightarrow y = 10$

Hence, the formula of **J** is $\underline{C_7H_{10}}$.

[0.5] correct working for either *x* or *y* (no e.c.f. from e(i) given).
[0.5] correct formula for **J** (with working)

2 (a) (i) No. of moles of $S_2O_3^{2-}$(aq) used = $0.500 \times \frac{25.56}{1000} = 0.01278$ mol **[0.5]**

No. of moles of I atoms in $I_xCl_y^-$ = 0.01278 mol = 0.0128 mol (3 s.f.) **[0.5]**

(ii) $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

No. of moles of AgCl(s) formed = $\frac{0.92}{(107.9+35.5)} = 6.416 \times 10^{-3}$ mol **[0.5]**

No. of moles of Cl atoms in $I_xCl_y^-$ = 6.42×10^{-3} mol **[0.5]**

(iii) Mole ratio of I : Cl in $I_xCl_y^-$ = 0.01278 : 6.42×10^{-3}
= 2 : 1 **[0.5]**

Hence, formula of the anion: $\mathbf{I_2Cl^-}$ **[0.5]**

No. of moles of I_2Cl^- = 6.416×10^{-3} mol

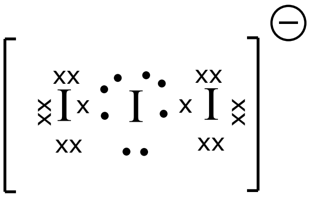
M_r of the metallic salt = $\frac{2.10}{6.416 \times 10^{-3}} = 327.3$ **[0.5]**

A_r of metal = 327.3 − (126.9 × 2) – 35.5 = 38.0

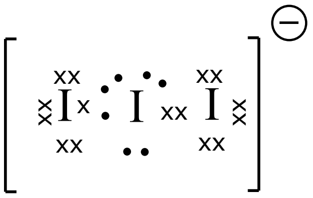
Identity of the Group 1 metal: Potassium / K **[0.5]**

(b) (i) A dynamic equilibrium refers to a reversible reaction in which the <u>forward and reverse reactions are taking place at the same rate</u> **[0.5]** resulting in <u>no overall changes in concentrations</u>/concentrations remaining constant. **[0.5]**

(ii)



or



[1]

(iii) When I_2 is added to KI(aq), increase in $[I_2]$ shifts the position of equilibrium 1 to the right to decrease $[I_2]$ **[1]**. Thus I_2 reacts with I^- to form I_3^- which can form ion-dipole interactions with water molecules. **[1]**

(iv) $K_c = \frac{[I_3^-]}{[I_2][I^-]} = \frac{0.850}{(0.040)^2}$ = 531.25 = 531 (3 s.f.) $mol^{-1}\ dm^3$ **[1]**

(v) $K_c >> 1$ (or large K_c) means the reaction has gone to completion / position of equilibrium lies far to the right. **[1]**

(vi) Let x be the no. of moles of I_2 added,

	I_2(aq)	+	I^-(aq)	$\rightleftharpoons$	I_3^-(aq)
initial /mol	$\frac{0.04 \times 100}{1000} + x$ $= 0.004 + x$		$\frac{0.04 \times 100}{1000}$ $= 0.004$		$\frac{0.85 \times 100}{1000}$ $= 0.085$
change/mol	−0.001		−0.001		+0.001
equilibrium/mol	0.003 + x **[0.5]**		0.003 **[0.5]**		0.086

$$531.3 = \frac{\frac{(0.086)}{V}}{(\frac{0.003 + x}{V})(\frac{0.003}{V})}$$

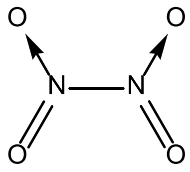
$$= \frac{(0.086)}{(0.003 + x)(\frac{0.003}{100/1000})} \Rightarrow x = 0.002396 \text{ mol}$$ **[1]**

$[I_2]_{new\ eqm} = \frac{(0.003 + 0.002396)}{0.100}$ = 0.0540 mol dm^{-3} (3 s.f.) **[1]**

(vii) ΔS for the forward reaction is negative as there is a decrease in the number of moles of aqueous particles during the forward reaction, **[1]** resulting in less ways to distribute the particles and their energy.

For the reaction to be spontaneous, $\Delta G = \Delta H - T\Delta S < 0$
Since ΔH and ΔS are −ve $\Rightarrow \Delta G = (-ve) - T(-ve)$
As T increases, magnitude of $T\Delta S$ increases, ΔG becomes less negative **[0.5]**. Thus the forward reaction becomes non-spontaneous when the T is too high / reaction becomes less spontaneous as T increases. **[0.5]**

3 (a) (i)



[1]

trigonal planar **[1]**

(ii) The lone electron-bond pair repulsion in NO_2 is weaker than bond pair-bond pair repulsion. **[1]**

(b) (i) $K_p = \frac{P_{(N_2O_4)}}{P_{(NO_2)}^{2}}$ **[1]**

(ii)

	$2NO_2(g)$	$\rightleftharpoons$	$N_2O_4(g)$
I / kPa	x		-
C / kPa	$-2a$		$+a$
E / kPa	$x-2a$		a

total initial P – total final P = 100 kPa = $x - (x - 2a + a) = a$
Equilibrium partial pressure of N_2O_4 = 100 kPa **[1]**

(iii) $K_p = \frac{P_{(N_2O_4)}}{P_{(NO_2)}^{2}}$

Equilibrium partial pressure of NO_2 = x – 200 kPa (see ICE table from **(ii)**)

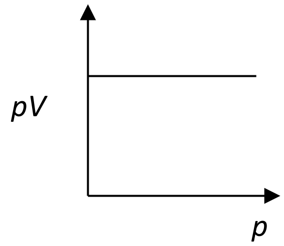
$$6.25 \times 10^{-2} = \frac{100}{(x-200)^2}$$

$$x - 200 = \sqrt{\left(\frac{100}{6.25 \times 10^{-2}}\right)} = 40$$

$x = 200 + 40 = \underline{240}$ kPa **[1]**

(iv) When the volume was decreased, total pressure increases **[0.5]**. This causes the equilibrium position to shift to the right **[1]** where there are less moles of gas so as to reduce the pressure **[0.5]**.

(c) (i)



[1]

(ii) The gas particles of a real gas have non-negligible volume compared to the volume of the container. **[1]**
There are intermolecular forces of attraction between real gas particles. **[1]**

(iii) Intermolecular forces of attraction**.** As *p* increases, particles become closer together and intermolecular forces of attraction become stronger, and there is greater deviation from ideality as the volume of gas becomes smaller than the volume expected if it were ideal
OR
there is greater deviation from ideality as the observed pressure is less than what it would be if the gas was ideal, causing pV to be even lower. **[1]**

(iv) Low pressure **[1]**

(v) Extrapolating the line to $p = 0$ (this is where a gas is most ideal),
$pV = 2538 \text{ Pa m}^{-3}$ **[1]**
(accept range of $2536 \leq pV \leq 2540$*)*

(vi) $pV = \left(\frac{m}{M_r}\right)RT$

$2538 = \left(\frac{56}{M_r}\right) \times 8.31 \times 150$

$M_r = \underline{27.5}$ **[1]**