1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B	D	C	B	C	D	B	D	D	A	C	A	B	B	A
16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
A	C	B	D	C	A	A	A	B	B	D	B	C	C	D

Q1(B)

1	Correct. Angle of deflection is proportional to $\frac{q}{m}$. Since $m_{electron} < m_{proton}$, electrons have a greater angle of deflection and are deflected to a larger extent than protons.
2	Correct. Electrons are attracted to the positive plate while protons are attracted to the negative plate i.e. the electron beam are deflected in the opposite direction to the proton beam.
3	Incorrect. The proton beans will travel in a curve path towards the negative plate.

Q2(D)

Q in the ionic nitrate, $\mathbf{Q}NO_3$, exists as $\mathbf{Q}^+$.
Since $\mathbf{Q}^+$ has 80 electrons, **Q** has 81 electrons and 81 protons. From the Periodic table, **Q** is the element thallium which belongs to group 13.

The nucleon number of **Q** is 81 + 122 = 203.

Q3(C)

A	Incorrect. 2nd IE of F : $F^+ \longrightarrow F^{2+} + e^-$ $[He]2s^22p^4 \quad [He]2s^22p^3$ 3rd IE of Al : $Al^{2+} \longrightarrow Al^{3+} + e^-$ $[Ne]3s^1 \quad [Ne]$ 2nd IE of F is greater because the electrons are removed from an inner electronic shell.
B	Incorrect 3rd IE of / electron removed from: F – 2p; Ne – 2p; Na – 2p; Mg – 2p; Al – 3s
C	Correct. 4th IE of Na : $Na^{3+} \longrightarrow Na^{4+} + e^-$ $[He]2s^22p^4 \quad [He]2s^22p^3$ 3rd IE of Ne : $Ne^{2+} \longrightarrow Ne^{3+} + e^-$ $[He]2s^22p^4 \quad [He]2s^22p^3$ Na^{3+} and Ne^{2+} have the same electronic configuration and experience the same shielding effect. 4th IE of Na is greater due to the greater nuclear charge of Na which causes the 2p electrons of Na^{3+} to experience a greater attraction to the nucleus, requiring more energy to remove.
D	Incorrect. Successive IE's always increase even if the electrons are removed from different shells. This is because the nuclear charge remains the same, but the number of electrons and shielding effect experienced by the remaining electrons decreases. Hence the electrostatic attraction between the nucleus and the outermost electron increases, resulting in an increase in energy required to remove each subsequent electron.

Q4(B)

Since there is a large jump between the 7th and 8th IE for element W, the 8th electron is removed from an inner shell i.e. W has 7 valence electrons and is from group 17.

Since W, X, Y and Z are consecutive elements, X is from group 18, while elements Y and Z are from groups 1 and 2 of the next period respectively.

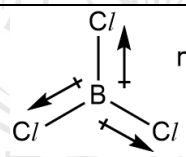
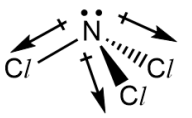
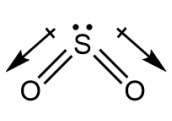
X, the group 18 element, has a higher first IE than W, the group 17 element of the same period since IE increases across the period.

X also has the higher first IE then Y and Z since Y and Z are from the next period and their valence electrons are further away from the nucleus and experience greater shielding effect.

Q5(C)

compound	C_2H_6	C_2H_4	C_2H_2
carbon-carbon bond	C–C	C=C	C≡C
bond energy	⟶ Bond energy increases due to increased number of shared electrons and increased attraction between bonding electrons and nuclei.		
bond length	⟶ Bond length decreases. In general, the stronger the bond, the shorter the bond length.		

Q6(D)

	molecule	molecular shape	polarity
A	BCl_3	trigonal planar ✓	~~polar~~ × non-polar
		 no overall dipole	
B	NCl_3	trigonal pyramidal ✓	~~non-polar~~ × polar
		 overall dipole	
C	SO_2	~~linear~~ × bent	~~non-polar~~ × polar
		 overall dipole	
D	$CHCl_3$	tetrahedral ✓	polar ✓

Q7(B)

Since all 4 compounds have similar M_r, their strengths of id-id interactions are similar.

M, P and Q can form stronger intermolecular hydrogen-bonding (due to the presence of –OH groups) compared to the weaker pd-pd interactions in N. Hence, N has a lower bp than M, P and Q.

M has 3 –OH groups and an average of 3 hydrogen bonds per molecule, resulting in more extensive hydrogen bonding compared P and Q which have 1 –OH group each, forming an average of 1 hydrogen bond per molecule. Hence, M has a higher BP than P and Q.

Due to presence of an addition electron-withdrawing C=O group in Q, the –OH group in Q is more polar, forming stronger intermolecular hydrogen bonds compared to P. Hence Q has a higher BP than P.

Q8(D)

A	Incorrect. This is Avogadro's Law.
B	Incorrect. This is an application of Dalton's Law, not the definition of Dalton's Law.
C	Incorrect. The partial pressure of a gas is given by the product of its *mole fraction* and the total pressure. Even then, this is not Dalton's Law.
D	Correct.

Q9(D)

Experiment 1 – SiO_2 solid does not dissolve in water i.e. SiO_2 solid remains.

Experiment 2 – SiO_2 solid does not react with, and hence does not dissolve in HCl(aq) i.e. SiO_2 solid remains.

Experiment 3 – SiO_2 solid does not react with, and hence does not dissolve in NaOH(aq) i.e. SiO_2 solid remains.
Note: SiO_2 only reacts with concentrated NaOH.

Q10(A)

No. of molecules = Amount in moles x Avogadro's constant

A	Ethyl methanoate, $CH_3CH_2O–CHO$ (M_r = 74.0) No. of molecules = $\frac{2.00}{74.0}$ x 6.02 x 10^{23} = **1.63 x 10^{22}**
B	Br_2(l) (M_r = 159.8) No. of molecules = $\frac{4.00}{159.8}$ x 6.02 x 10^{23} = 1.51 x 10^{22}
C	No. of molecules = $\frac{550}{24000}$ x 6.02 x 10^{23} = 1.38 x 10^{22}

D	No. of molecules = 1.55×10^{22}

Q11(C)

Amount of $H_2SO_4 = \frac{20.0}{1000} \times 5.00 = 0.100$ mol

Amount of $NaOH = \frac{20.0}{1000} \times 5.00 = 0.100$ mol

$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$

Since H_2SO_4 reacts with NaOH in a 1:2 ratio, NaOH is limiting.

$q = mc\Delta T = (20.0 + 20.0)(4.18)(50.0 - 25.0)$
$= 4180$ J

$\Delta H = -\frac{q}{n_{NaOH}} = -4180/0.100 = -41800$ J mol^{-1}
$= -41.8$ kJ mol^{-1}

Q12(A)

This is a graph of rate of forward reaction against time and the rate equation for the forward rate is rate = $k(p_{CO_2})$.

At time t, the pressure i.e. p_{CO_2} is lowered, causing a decrease in the forward rate just after time t as seen in options **A** and **B**.

The pressure was then allowed to return to atmospheric pressure, so p_{CO_2} increases back to the initial pressure and the forward rate increases back to the original rate as seen in option **A**.

Q13(B)

1	Correct. For the hydrogen and bromine reaction, HBr appears in the denominator of the rate equation. When [HBr] increases, rate decreases i.e. the formation of HBr slows down the rate of reaction.
2	Correct. The rate equation for H_2 and Br_2 involves many species. It is unlikely that so many species will collide and be involved in a single step reaction. Also, the stoichiometry of the reactants reaction is not the same as the orders of reaction in the rate equation. This is not likely to be a single step reaction. Since the rate equation involves 1 mole of H_2 and 1 mole of I_2 which is the same as the stoichiometry of the reaction between H_2 and I_2, it could be a single step reaction.
3	Incorrect. Using the rate equation for reaction 1, when $[Br_2]$ x 2, rate x $2^{1.5} = 2.8$ i.e. the rate of reaction 1 is not doubled when $[Br_2]$ is doubled.

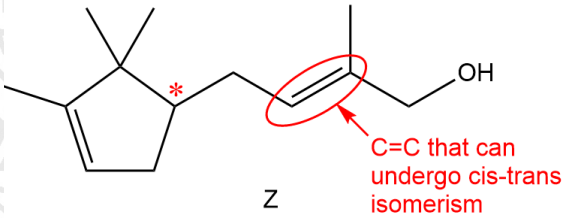
Q14(B)

Stereoisomers = cis-trans isomers and enantiomers

Max no. of stereoisomers = 2^{m+n}

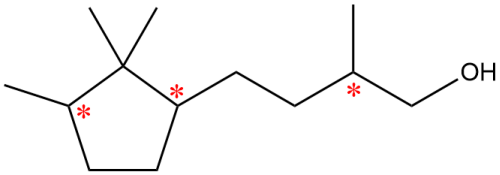
m = no. of double bonds that can undergo cis-trans isomerism

n = no. of chiral centres



Z

No. of stereoisomers = $2^{1+1} = 4$



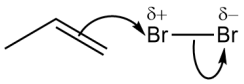
Q

No. of stereoisomers = $2^3 = 8$

Q15(A)

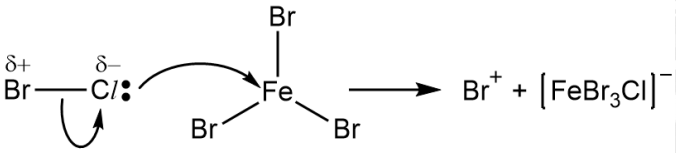
A	Correct. In the propagation steps, methylproprane reacts with the X● radical generated in the initiation step. $(CH_3)_3CH + X\bullet \longrightarrow (CH_3)_3C\bullet + HX$ -- (a) $(CH_3)_3C\bullet + X_2 \longrightarrow (CH_3)_3CX + X\bullet$ $(CH_3)_3CX$ i.e. C_4H_9X is generated in one of the propagation steps.
B	Incorrect. In the termination steps, two radicals collide to form non-radical products. Radicals, like $(CH_3)_3C\bullet$, will not be produced.
C	Incorrect. In the overall reaction, bonds broken = X–X and C–H bonds formed = H–X and C–X. ΔH when X = Br $= 193 + 410 - (366 + 280) = -43$ kJ mol^{-1} ΔH when X = C*l* $= 244 + 410 - (431 + 340) = -117$ kJ mol^{-1} The reaction with chlorine is more exothermic.
D	Incorrect. In the initiative step, a halogen *radical*, **not** ion, is produced.

Q16(A)

A	Correct. In the slow step, the carbon-carbon π bond is donated to the electrophile because the π bond is weaker than the σ bond (due to less effective orbital overlap in the π bond) and is more easily broken. 
B	Incorrect. See explanation in option A.
C	Incorrect. In the slow step, the electrons are *donated* from the C=C which makes the C=C a nucleophile.
D	Incorrect. See explanation in option A.

Q17(C)

In the absence of sunlight, homolytic breaking of the Br–C*l* to form the respective radicals does not take place i.e. no reaction to the $-CH_3$ side chain of methylbenzene. Reject options **A** and **B**.



The iron-containing catalyst (e.g. $FeBr_3$) acts as a Lewis acid and accepts a pair of electrons from the δ– chlorine in BrC*l* to generate the Br^+ electrophile and $[FeBr_3C\mathit{l}]^-$. The Br^+ electrophile then undergoes electrophilic substitution with the benzene ring in methylbenzene, substituting one Br atom into the benzene ring.

Q18(B)

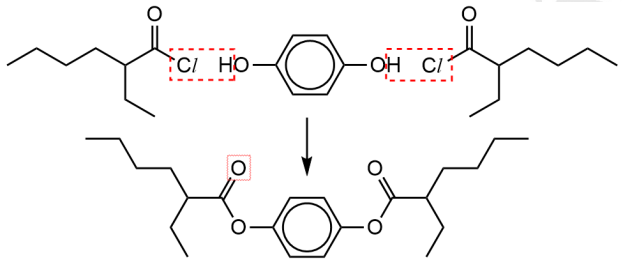
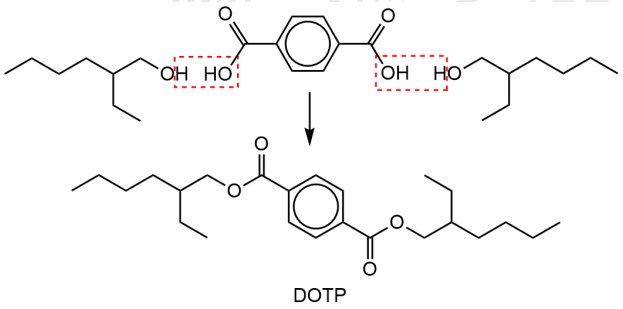
1	No. While the statement is true, it does not help to explain the difference in rate of the two halogenoalkanes.
2	Yes. Br has more electron shells than C*l*. Hence, the valence electrons used in Br for bonding with carbon is further away, and more shielded, from its nucleus than in C*l*. This results in weaker attraction by the Br nucleus for the shared electrons in the C−Br bond compared to the case with C*l*, contributing to the C−Br bond being weaker than the C−C*l* bond.
3	Yes. Br has more electron shells than C*l*, resulting in a larger atomic radius of Br compared to C*l* which contributes to the C–Br bond being weaker than the C−C*l* bond.
4	No. While the statement is true, it does not help to explain the difference in rate of the two halogenoalkane. This is because the large number of electron shells causes a significant shielding of the valence electrons of Br from the attraction of the high nuclear charge, causing the resultant attraction experienced by the valence electrons to be lower.

Q19(D)

Student P is incorrect because organic compounds (e.g. alcohols) do not give a positive test with warm silver nitrate solution i.e. the organic compound does not have to be a halogenoarene either.

Student Q is incorrect because the organic compound can be a fluoroalkane, which is a halogenoalkane. Fluoroalkanes do not give a positive test with warm silver nitrate solution as the C–F bond very strong and is too strong to be broken to form F^- ions.

Q20(C)

A	Incorrect. In the H2 syllabus, acyl chlorides do not react with carboxylic acids. Therefore, mixing the two compounds does not give any product.
B	Incorrect. The reaction gives the following product which is not DOTP. 
C	Correct. In the presence of a suitable catalyst, a reactions takes place between the reactants to give DOTP as the product. 
D	Incorrect. The structure of the alcohol drawn has only 7 carbons whereas the alcohol part of the ester in DOTP has 8 carbons. The reaction with these reactants will not give DOTP as the product.

Q21(A)

The relative basicity of amines decrease in the order : tertiary > secondary > primary.

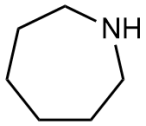
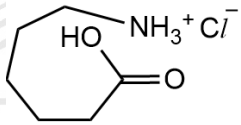
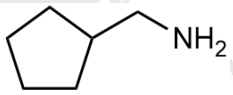
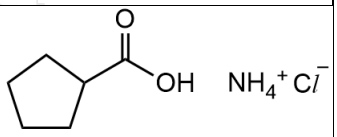
Tertiary, secondary and primary amines have 3, 2 and 1 alkyl groups bonded to the N atom respectively.

With more electron-donating alkyl groups (R–), there is increasing electron density at the N atom, increasing the availability of the lone pair of electrons to form a dative covalent bond with H^+.

Q22(A)

1	Yes. The orbital containing the lone pair of electron on N overlaps with the π-electron cloud of the C=O which allows the lone pair of electrons on N to delocalize into the C=O, reducing the availability of the lone pair on N to form a dative bond with H^+.
2	No. The delocalization gives the C–N bond a partial double bond character which strengthens the bond, but this does not affect the acid-base properties of an amide.
3	Yes. When the N atom of an amide is protonated, the lone pair of electrons N is used to form a dative bond with H^+ and the delocalization of the lone pair on N to the C=O group is lost, causing the ion to be less stable.

Q23(A)

	Product of reaction with	
	$LiAlH_4$ (reduction of amide)	warm HCl(aq) (acidic hydrolysis)
A	 $C_6H_{13}N$	 $C_6H_{14}NO_2Cl$
B	 $C_6H_{13}N$	 $C_6H_{10}O_2$
C	$CH_3(CH_2)_4CH_2NH_2$ $C_6H_{15}N$	$CH_3(CH_2)_4COOH$ $NH_4^+Cl^-$ $C_6H_{12}O_2$
D	$CH_3CH_2CH_2CH_2NHCH_2CH_3$ $C_6H_{15}N$	$CH_3CH_2CH_2COOH$ $Cl^- H_3\overset{+}{N}CH_2CH_3$

Q24(B)

The –COOH group is more acidic, and has a lower pK_a, than the $-NH_3^+$ group. The reaction associated with pK_{a1} involves the dissociation of the more acidic –COOH, so it should have the lower pK_a value of 2.4. Therefore, pK_{a2} is 9.8. Reject options **C** and **D**.

Since the pH of 13 > pK_{a1}, the dominant form is where the –COOH group is deprotonated to form $-COO^-$.

Since the pH of 13 > pK_{a2}, the dominant form is where the $–NH_3^+$ group is deprotonated to form $–NH_2$.

The formula of glycine at pH 13 is therefore $H_2N–CH_2–CO_2^-$.

Note: when pH < pK_a of acidic group, the dominant form is the protonated form. When pH > pK_a of acidic group, the dominant form is the deprotonated form.

Q25(B)

The reaction of interest is $O_2 + Cr_2O_4^{2-} \longrightarrow CrO_4^{2-}$ in alkaline medium (since the reaction is done in sodium hydroxide).

$Cr_2O_4^{2-} + 8OH^- \longrightarrow 2CrO_4^{2-} + 4H_2O + 6e^-$ -- **(1)**

$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$ -- **(2)**

2x**(1)**+3x**(2)**:

$2Cr_2O_4^{2-} + 4OH^- + 3O_2 \longrightarrow 4CrO_4^{2-} + 2H_2O$

3 mol of O_2 react with 2 mol of $Cr_2O_4^{2-}$

i.e. <u>1.5 mol of O_2</u> react with 1 mol of $Cr_2O_4^{2-}$

Q26(D)

(1) -- $Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$ $\quad E^\ominus = +0.34$ V

(2) -- $2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$ $\quad E^\ominus = 0.00$ V

$E^\ominus_{cell} = 0.34 – 0.00 = +0.34$V

A	Incorrect. When pressure of H_2 decreases, the position of equilibrium (2) shifts to the right, making the value of $E(H^+/H_2)$ more positive, leading to a less positive cell potential.
B	Incorrect. Increasing $[H^+]$ causes the position of equilibrium (2) to shift right, making the value of $E(H^+/H_2)$ more positive, leading to a less positive cell potential.
C	Incorrect. Changing from $CuSO_4(aq)$ to $Cu(NO_3)_2(aq)$ maintains the concentration Cu^{2+} at 1 mol dm^{-3}. There is no change in the position of equilibrium of (1) and the cell potential remains the same.
D	Correct. 1.0 mol dm^{-3} ethanoic acid, a weak acid, provides less than 1.0 mol dm^{-3} of H^+ in the hydrogen electrode. This causes the position of equilibrium (2) to lie more to the left, making the value of $E(H^+/H_2) < 0$, leading to a more positive cell potential.

Q27(B)

Amount of $Al = \frac{0.27}{27.0} = 0.0100$ mol

$Al^{3+} + 3e^- \longrightarrow Al$

Amount of e^- transferred = 3(0.0100) = 0.0300 mol

Since $Q = n_eF$,

$F = \frac{Q}{n_e} = \frac{2904}{0.0300} = 96800$ C mol^{-1}

Since Faraday constant = Avogadro's number x charge of $1e^-$

i.e. 96800 = Avogadro's number x 1.6 x 10^{-19}

Avogadro's number = 6.05 x 10^{23}

Q28(C)

$E^\ominus(Ni^{2+}/Ni) = –0.25$ V

$E^\ominus(Cu^{2+}/Cu) = +0.34$ V

At the cathode, Cu^{2+} will be preferentially reduced since $E^\ominus(Cu^{2+}/Cu) > E^\ominus(Ni^{2+}/Ni)$.

$Q = It = n_eF$

$n_e = \frac{It}{F} = \frac{0.50(1.5 \times 60 \times 60)}{96500} = 0.02798$ mol

$Cu^{2+} + 2e^- \longrightarrow Cu$

Amount of Cu formed = $\frac{0.02798}{2} = 0.01399$ mol

Mass of Cu formed = 0.01399(63.5) = 0.888

= 0.89 g

Q29(C)

Note:

1. Students should be familiar with the data in the Data Booklet and be aware that a variety of $E^\ominus$ values are provided for vanadium species.

$V^{2+} + 2e^-$	$\rightleftharpoons$	V	–1.20
$V^{3+} + e^-$	$\rightleftharpoons$	V^{2+}	–0.26
$VO^{2+} + 2H^+ + e^-$	$\rightleftharpoons$	$V^{3+} + H_2O$	+0.34
$VO_2^+ + 2H^+ + e^-$	$\rightleftharpoons$	$VO^{2+} + H_2O$	+1.00
$VO_3^- + 4H^+ + e^-$	$\rightleftharpoons$	$VO^{2+} + 2H_2O$	+1.00
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	Zn	–0.76

2. Therefore, students should be aware of the possibility, and check by calculating relevant

$E^{\ominus}_{cell}$ value, that VO_2^+ may be reduced to VO^{2+}, which may be reduced to V^{3+}, which may be reduced to V^{2+}, which may be reduced to V.

3. This is especially since *excess* Zn was added, which would provide more than sufficient reducing agent to reduce the vanadium species.
4. To do this question, you do not need write the balanced equations in your working. You just need to check the final oxidation state of vanadium that VO_2^+ is reduced to.

Reaction (eqns are not balanced)	$E^{\ominus}_{cell}$ / V
$Zn + VO_2^+ \rightarrow Zn^{2+} + VO^{2+}$	1.00–(−0.76) = +1.76 > 0 i.e. VO_2^+ reduced to VO^{2+}
$Zn + VO^{2+} \rightarrow Zn^{2+} + V^{3+}$	0.34–(−0.76) = +1.10 > 0 i.e. VO^{2+} reduced to V^{3+}
$Zn + V^{3+} \rightarrow Zn^{2+} + V^{2+}$	–0.26−(−0.76) = +0.50 > 0 i.e. V^{3+} reduced to V^{2+}
$Zn + V^{2+} \rightarrow Zn^{2+} + V$	–1.20−(−0.76) = −0.44 > 0 i.e. V^{2+} **not** reduced to V

Overall, Zn reduces VO_2^+ to V^{2+} i.e. option **C**.

Q30(D)

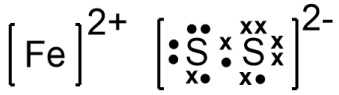
A transition element has high melting point (like in option 1) and high density (like in option 2).

Question 1

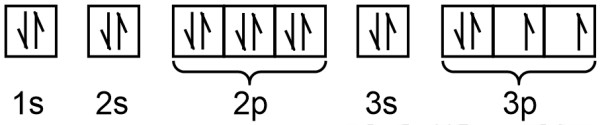
(a)(i) $A_r(\text{sulfur}) = \frac{[31.97(63.8) + 33.97(2.8)]}{63.8 + 2.8}$

$= 32.05$ (to 4 s.f.)

(a)(ii)



(b)



(c)(i) It is the energy required to remove 1 mole of electrons from 1 mole of gaseous sulfur atoms to form 1 mole of gaseous S^+ ions.

Note: Energy *required*, **not** change or released

(c)(ii) The first ionization energy across Period 3 elements generally increases. Across Period 3, the nuclear charge increases while the shielding effect is approximately constant, leading increasing attraction of the nucleus for the valence electrons.

For sulfur, there is additional interelectronic repulsion between the paired electrons in the valence 3p subshell, requiring less energy to remove the valence electron.

Note: students need to mention that, for sulfur, the electron is removed from the 3p subshell.

(d)(i) In CS_2, sp hybridisation results when one 2s and one 2p orbital of C mix to form two sp hybrid orbitals. There are two unhybridised p-orbitals in C.

(d)(ii) The sp^2 hybrid orbital of S with 1 electron overlaps head-on with the sp hybrid orbital of C to form a σ bond. The unhybridised p-orbital of S with 1 electron overlaps side-to-side with an unhybridised p-orbital of C to form a π-bond.

Note: Students can include diagrams to aid their explanation.

Question 2

(a)(i) Down group 1, the ionic radius increases due to the increase in the number electron shells, causing the valence electrons to be further away from the nucleus.

(a)(ii) Cs^+ has a larger ionic radius than Li^+, Na^+ and K^+ which allows it to accommodate more anions around itself.

(b)

ionic solid	LE / kJ mol^{-1}	interionic distance / nm	cationic charge	anionic charge
NaC*l*	−771	0.276	+1	−1
NaF	−902	0.231	+1	−1
MgO	−3899	0.205	+2	−2

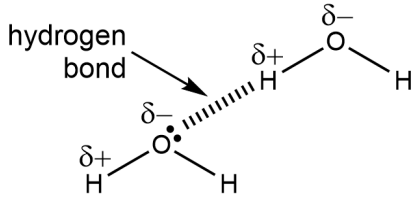
The two factors that affect the magnitude of lattice energy are ionic charge and interionic distance.

When the ionic distance increases from 0.231 nm (NaF) to 0.276 (NaC*l*), the magnitude of lattice energy decreases slightly from 902 to 771.

Comparing NaF and MgO, which have similar interionic distances, when the cationic and anionic charges are each doubled from NaF to MgO, the magnitude of lattice energy more than quadrupled.

Hence, the ionic charges have a greater effect on the magnitude of lattice energy.

(c)(i)



(Diagram should include lone pair of electrons on O, dipoles on O–H and labelling of the interaction)

(c)(ii) The energy released from the formation of the ion-dipole interactions between Na^+ and Cl^- ions with water compensate for the energy required to break the ionic bonds in NaCl, whereas the significantly weaker interactions formed between Na^+ and Cl^- ions and hexane is unable to do so.

(d)(i) When NH_4Cl dissolves, the NH_4^+ and Cl^- ions are no longer held in fixed positions in the ionic lattice as they become free-moving aqueous ions, increasing the disorder, resulting in a positive $\Delta S^\ominus$.

(d)(ii) $\Delta G^\ominus$ is negative since NH_4Cl dissolves spontaneously in water at 298 K without any external assistance.

(d)(iii) For NH_4Cl to dissolve in water, $\Delta G^\ominus < 0$ i.e.

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

$15.2 - T(\frac{73.5}{1000}) < 0$

$T > 207$ K

Minimum T = 207 K

At 207 K i.e. −66 °C, water exists as solid ice which NH_4Cl is unable to dissolve in.

Question 3

(a) More energy is required to break the stronger H–F bond (bond energy = 562 kJ mol^{-1}) than the H−Cl (bond energy = 431 kJ mol^{-1}) in the dissociation of the acids.

(b) $[H^+] = \sqrt{0.0500 \times 5.62 \times 10^{-4}}$

$= 0.005301$ mol dm^{-3}

$pH = -\log(0.005301) = 2.28$

(c)(i) $HF(aq) + OH^-(aq) \longrightarrow F^-(aq) + H_2O(l)$

$F^-(aq) + H_3O^+(aq) \longrightarrow HF(aq) + H_2O(l)$

Note: students should make use of H_3O^+ (as specified in the question) instead of H^+.

(c)(ii) HCl is a strong acid that has fully dissociated in water. When a small amount of OH^- is added, H^+ in the mixture is reacted and not replenished. Therefore, pH change is significant. **OR**

Cl^- is a very weak base as it is the conjugate base of a strong acid (HCl) and is unable to react with and remove any H_3O^+ added. Therefore, the mixture is unable to act as a buffer.

(c)(iii) Amount of NaF in 200 cm^3 of buffer **T** prepared = $(\frac{100}{1000})(1.78) = 0.178$ mol

Amount of NaF in 75.0 cm^3 of buffer **T**

$= (\frac{75}{200})(0.178)$

$= 0.06675$ mol

Amount of H^+ from $H_2SO_4(aq)$

$= 2(\frac{50.0}{1000})(0.100) = 0.0100$ mol

Since F^- from NaF reacts with H^+ added, amount of F^- remaining

$= 0.06675 - 0.0100 = 0.05675$ mol

$[F^-]_{remaining} = \frac{0.05675}{\frac{50.0 + 75.0}{1000}} = 0.454$ mol dm^{-3}

(d)(i) The pK_a value of CCl_3COOH is smaller than CH_3COOH and tells us that the extent of dissociation of CCl_3COOH is greater than that of CH_3COOH.

(d)(ii) x = 0.2. F is more electronegative than Cl and exerts a stronger electron-withdrawing effect which disperses the negative charge on $–COO^-$ to a greater extent, making CF_3COO^- more stable than CCl_3COO^-. Hence, CF_3COOH is a stronger acid with a smaller value of pK_a.

(e)(i) Let the solubility of CaF_2 be s mol dm^{-3}. At equilibrium, $[Ca^{2+}]$ = s mol dm^{-3} and $[F^-]$ = 2s mol dm^{-3}.

$K_{sp} = (s)(2s)^2 = 3.90 \times 10^{-11}$
$s = 0.0002136$ mol dm^{-3}

$[F^-] = 2s = 2(0.0002136)$
$= 0.000428$ mol dm^{-3}

(e)(ii) In acidic solutions, H^+ reacts with F^- to form HF, causing the $[F^-]$ to be lower. This causes the position of equilibrium of $CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^-(aq)$ to shift right to counteract the decrease in $[F^-]$, causing more CaF_2 to dissolve.

Question 4

(a) PTFE is a saturated organic compound containing a large number of C–F (485 kJ mol^{-1}) and C–C (350 kJ mol^{-1}) bonds which are very strong and require a lot of energy to break, making PTFE chemically unreactive.

(b) In the atmosphere, UV light provides sufficient energy to break the C−C*l* bond in $CHCl F_2$ to form C*l*● radicals which react with ozone, depleting the ozone in the atmosphere.

(c) High temperature and low pressure.

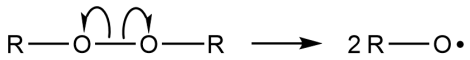
(d)(i) It is the breaking of a covalent bond such that one electron goes to each of the atoms, forming free radicals.

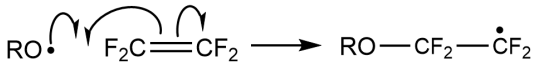
(d)(ii)

reaction	name
A	Initiation
B	Propagation
C	Propagation
D	Termination

(d)(iii) Free radical addition

(d)(iv)

reaction **A** 

reaction **B** 

(d)(v) RO–OR + 12 $F_2C{=}CF_2 \longrightarrow$ product

		BE / kJ mol^{-1}
Bonds broken	1 O–O bond	1(150)
	12 carbon–carbon π bonds (Note: this can also be seen as *breaking 12 C=C & **forming 12 C–C	12(*610 – **350)
Bonds formed	2 C–O bonds	2(360)
	11 C–C bonds	11(350)

$\Delta H_r^{\ominus}$
$= 150 + 12(610 - 350) - 2(360) - 11(350)$
$= -1300$ kJ mol^{-1}

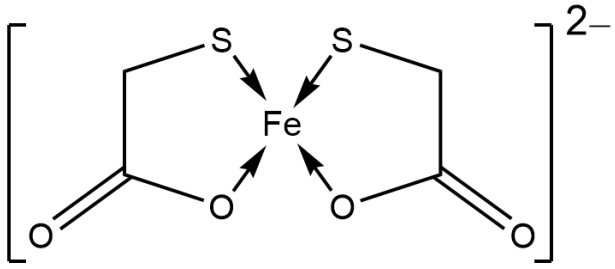
(d)(vi) Free radical **P** would be the major species because it is a secondary radical and the p-orbital containing the lone-electron overlaps with the π-electron cloud of benzene, allowing radical **P** to be resonance stabilized.

(**Q** is a primary radical with only one electron-donating group and the absence of any resonance stabilisation of radical.)

Question 5

(a) Thioglycolic acid acts as a reducing agent as it reduces Fe^{3+} to Fe^{2+} as shown in equation 5.1.

(b)



(c) Ammonia was added to react with thioglycolic acid to form the corresponding anion, which can then complex with Fe^{2+} to form the pink-coloured complex, **M**.

OR

Ammonia was added to provide the basic conditions necessary for thioglycolic acid to complex with Fe^{2+} to form the pink-coloured complex, **M**.

(d) $Fe(SCH_2COOH)_2 + 2NH_3 \longrightarrow [Fe(SCH_2COO)_2]^{2-} + 2NH_4^+$

(e)(i) $[Fe(H_2O)_6]^{2+}(aq) + \underline{2}NH_3(aq) \longrightarrow$ **$\underline{[Fe(OH)_2(H_2O)_4](s) + 2NH_4^+(aq)}$**

(e)(ii) Green ppt of $Fe(OH)_2$ is oxidized by O_2 in the air to form a brown ppt of $Fe(OH)_3$.

(f) 10.0 ppm of Fe^{2+}
= 10.0 x 10^{-3} g of Fe^{2+} in 1000 cm^3 of solvent

Mass of Fe^{2+} in 100 cm^3 solution
= 1.0 x 10^{-3} g of Fe^{2+}

Amount of Fe^{2+} in 100 cm^3 solution
= $\frac{1.0 \times 10^{-3}}{55.8}$ = 1.792 x 10^{-5} mol
= Amount of Fe^{2+} in 10.00 cm^3 solution drawn from 250 cm^3 volumetric flask.

Amount of Fe^{2+} in 250 cm^3 volumetric flask
= $(\frac{250}{10})(1.792 \times 10^{-5})$ = 4.48 x 10^{-4} mol
= amount of Fe^{2+} from *x* g of solid

x = (4.48 x 10^{-4})(392.0) = 0.176 g

(g) Amount of **Y** = $\frac{1}{139}$ = 0.007194 mol
Mole ratio of Y : Fe
= 0.007194 : 2.40 x 10^{-3}
= 3 : 1

Since the complex of **Y** and Fe is an octahedral complex, 3 mol of **Y** forms 6 dative bonds with the central Fe i.e. each **Y** forms two bonds.

Amount of **Z** = $\frac{1}{560.0}$ = 0.001786 mol
Mole ratio of Z : Fe
= 0.001786 : 1.78 x 10^{-3}
= 1 : 1

Since the complex of **Z** and Fe is an octahedral complex, 1 mol of **Z** forms 6 dative bonds with the central Fe i.e. each **Z** forms six bonds.

Question 6

(a)(i)

Element	Cr	H	N	S	C*l*	O
No. of moles	$\frac{19.4}{52}$ = 0.3731	$\frac{5.6}{1}$ = 5.6	$\frac{26.1}{14}$ = 1.864	$\frac{11.9}{32.1}$ = 0.3707	$\frac{13.2}{35.5}$ = 0.3718	$\frac{23.8}{16}$ = 1.488
Mole ratio (divide by 0.3707 through-out)	1	15	5	1	1	4

Using the above mole ratio of the elements, the formula of complex **A** is $CrH_{15}N_5SClO_4$ since the M_r of the empirical formula is the same as that of complex **A**.

(a)(ii) Since both complex cations contain 6 ligands, the shape of each complex cation is octahedral. The bond angle is 90°.

(a)(iii) $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

(a)(iv) Reaction of **A** with $HNO_3(aq)$ followed by $AgNO_3$ gave white ppt implies that **A** contains a chloride ion as the counter-anion i.e. the complex cation has the formula $[CrH_{15}N_5SO_4]^+$.

A has 2 different types of ligands, we can deduce from the formula that there is 1 SO_4^{2-} and 5 NH_3 ligands.

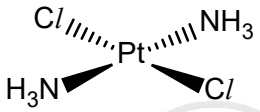
Complex ion in **A** is $[Cr(NH_3)_5(SO_4)]^+$.

(b)(i) Due to the higher proportion of H_2O in the cell, when cisplatin enters the cell, the position of equilibrium of equation 6.1 shifts

to the right, causing a significant amount of chloride to be substituted. **OR**
Due to the lower concentration of chloride in the cell, when cisplatin enters the cell, the position of equilibrium of equation 6.1 shifts to the right to increase the concentration of chloride in the cell, causing a significant amount of chloride to be substituted.

(b)(ii) The ligands contain electron pairs which can be donated to the central Pt ion to form dative covalent bonds.

(b)(iii)



(b)(iv) The 2 specific ligands on DNA are a specific distance from each other and the distance matches the distance of the 2 cis-H_2O groups in cis-$[Pt(NH_3)_2(H_2O)_2]^{2+}$ which the specific ligands on DNA will substitute.

For the trans-$[Pt(NH_3)_2(H_2O)_2]^{2+}$ from transplatin, the 2 trans-H_2O groups are much further away and do not match the specific distance of the ligands on DNA.

(c) Before heating, plane-polarised light passes through undisturbed because **D** has a plane of symmetry and is not optically active.

After heating, plane polarized light still passes through the sample undisturbed. The final mixture contains **D** (optically inactive) and a 1:1 ratio of **C** and **E.** Isomers **C** and **E** are enantiomers. Since **C** and **E** are in a 1:1 ratio, the optical activity of **C** is exactly cancels out the optical activity of **E**.

Question 1

(a)(i) $I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$

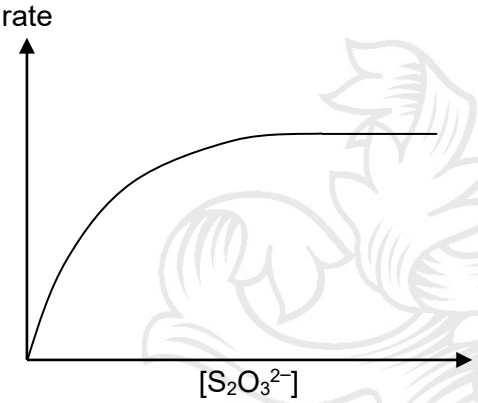
$E^{\ominus} = 0.54 - 0.09 = +0.45$ V

(a)(ii) $Cl_2 + 2e^- \longrightarrow 2Cl^-$ **--- (1)**

$5H_2O + S_2O_3^{2-} \longrightarrow 2SO_4^{2-} + 10H^+ + 8e^-$ **---(2)**

4 x **(1)** + **(2)** : $4Cl_2 + 5H_2O + S_2O_3^{2-} \longrightarrow 8Cl^- + 2SO_4^{2-} + 10H^+$

(b)

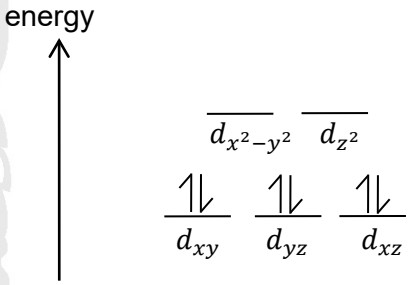


At low $[S_2O_3^{2-}]$, not all of the active sites of the enzymes are occupied. Therefore, as $[S_2O_3^{2-}]$ increases, the rate increases.

At high $[S_2O_3^{2-}]$, all the active sites of the enzymes are occupied and any increase in [substrate] will not have any effect on the reaction rate. Hence, the rate is constant despite increasing $[S_2O_3^{2-}]$.

(c)

(d)(i) Electronic configuration of Fe^{2+} = [Ar] $3d^6$



(d)(ii) The H_2O ligand in deoxyhaemoglobin and O_2 ligand in oxyhaemoglobin cause different extents of d-d splitting in the Fe^{2+} centres, causing the energy gaps between their two levels of d-orbitals to be different. The electrons in their lower level d-orbitals will absorb different wavelengths of visible light to be promoted. The colour observed, which is complementary to the colour absorbed, is different.

(d)(iii) When 50% of Hb is converted to $Hb(O_2)_4$, $[Hb] = [Hb(O_2)_4] = x$.

Value of $K_c = \frac{[Hb(O_2)_4]}{[Hb][O_2]^4} = \frac{x}{(x)(7.82 \times 10^{-3})^4} = 2.67 \times 10^8$

(e) $Cu_2SO_4(s) \longrightarrow CuSO_4(aq) + Cu(s)$

solution **G** solid **H**

$Cu^{2+}(aq) + 2NH_3(aq) + 4H_2O(l) \rightleftharpoons Cu(OH)_2(s) + 2NH_4^+(aq)$

pale blue ppt **I**

OR $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

$Cu^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Cu(OH)_2(s)$

pale blue ppt **I**

$Cu(OH)_2(s) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$

dark blue solution **J**

$Cu(s) + 4\ HNO_3(l) \longrightarrow Cu(NO_3)_2 + 2NO_2(g) + 2H_2O(l)$

blue solution **K**

Question 2

(a)(i) For an ideal gas, the size of the gas particles is negligible compared to the volume of the container.

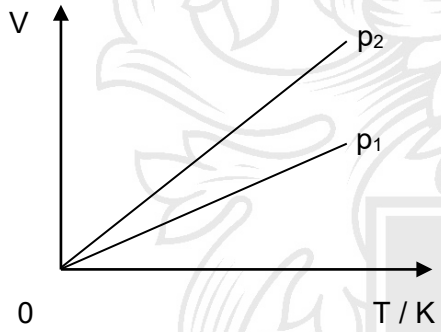
The gas particles **exert negligible attractive forces** on one another.

Collisions between the gas particles are perfectly **elastic**.

(a)(ii) $pV = nRT$

$V = (\frac{nR}{p})T$

Each graph is a straight line with a positive gradient of $(\frac{nR}{p})$ passing through the origin. Since $p_1 > p_2$, $(\frac{nR}{p_1}) < (\frac{nR}{p_2})$ i.e. gradient at p_1 is less steep than gradient at p_2.



(b) $pV = nRT$

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

$\frac{m}{V} = \frac{pM_r}{RT}$

density in g m^{-3} $= \frac{pM_r}{RT}$

$= \frac{(700)(44)}{(8.31)(273-65)}$

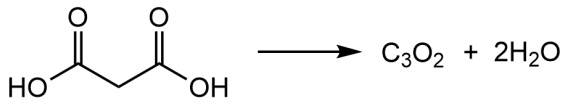
$= 17.82$ g m^{-3}

1 $m^3 = 10^6$ $cm^3 \longrightarrow 17.82$ g

1 $cm^3 \longrightarrow 1.782 \times 10^{-5}$ g

Average surface density $= 1.78 \times 10^{-5}$ g cm^{-3}

(c)



skeletal formula of propanedioic acid

$\longrightarrow C_3O_2 + 2H_2O$

(d) $M_r(H_2O) = 2(1.0) + 16.0 = 18.0$

$M_r(CO_2) = 12.0 + 2(16.0) = 44.0$

Amount of $(CO_2)_8(H_2O)_{46}$

$= \frac{650000}{8(44.0)+46(18.0)}$

$= 550.8$ mol

1 mol of $(CO_2)_8(H_2O)_{46}$ required 8 mol of CO_2 to form.

Amount of $CO_2 = 8(550.8) = 4406$ mol

Volume of CO_2 at rtp

$= 4406(24.0) = 106\,000$ dm^3

(e)(i) The shape is linear about each C atom in ethyne. On each of the C atom, one sp hybrid orbital overlaps head-on with the 1s orbital of H to form a σ-bond; another sp hybrid orbital overlaps heads-on with the sp hybrid orbital of the other C atom to form another σ-bond.

The two unhybridised p-orbitals of one C atom overlaps side-on with the two unhybridised p-orbitals of the other C atom to form 2 π-bonds.

These result in a triple bond between the 2 C atoms.

(e)(ii)

	$2CH_4(g)$	⇌	$C_2H_2(g)$	+	$3H_2(g)$
Initial amt / mol	0.800		0		0
Change in amt / mol	−0.6(0.80) = −0.48		0.5(+0.48) = +0.24		1.5(+0.48) = +0.72
Eqm amt / mol	0.32		0.24		0.72

Total amount of gases at eqm

$= 0.32 + 0.24 + 0.72 = 1.28$ mol

Eqm partial pressure of CH_4

$= \frac{0.32}{1.28} \times 2.50 \times 10^6 = 625000$ Pa

Eqm partial pressure of C_2H_2

$= \frac{0.24}{1.28} \times 2.50 \times 10^6 = 468800$ Pa

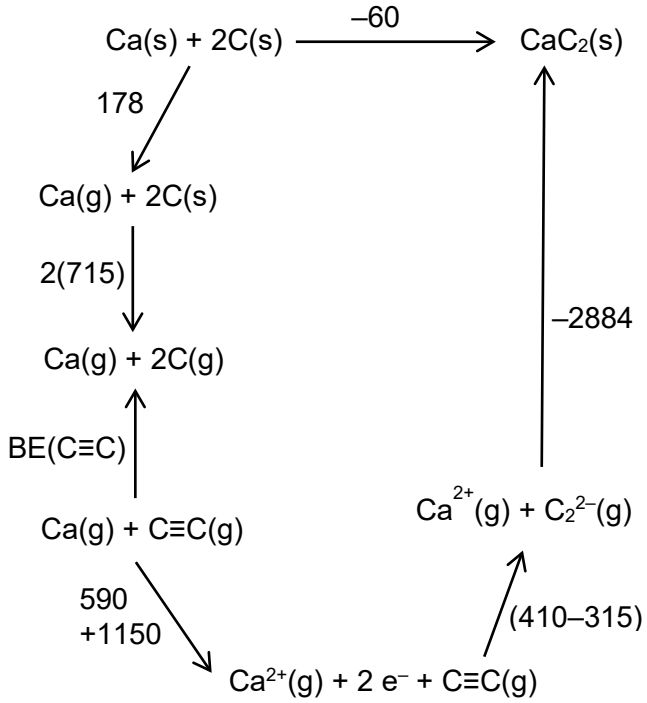
Eqm partial pressure of H_2

$= \frac{0.72}{1.28} \times 2.50 \times 10^6 = 1406000$ Pa

$K_p = \frac{(468800)(1406000)^3}{(625000)^2}$

$= 3.34 \times 10^{12}$ Pa^2

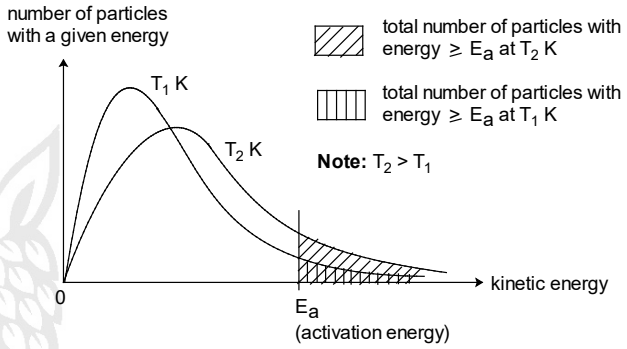
(f)



BE(C≡C) = 590 + 1150 + 410 – 315 – 2884
−(−60) + 178 + 2(715)
= +619 kJ mol^{-1}

Question 3

(a) As temperature increases from T_1 to T_2 K, the average kinetic energy of the reactant particles increases. As such, significantly more reactant particles have energy greater than or equal to the activation energy of the reaction. This is shown by the significantly larger shaded area at a higher temperature in the diagram below.



Consequently, the frequency of effective collisions increases accordingly, and hence the reaction rate increases.

An increase in temperature also results in a larger rate constant, and hence an increase in the reaction rate.

(b) The order of reaction is the power to which the concentration of a reactant is raised in the rate equation.

The rate constant of a reaction is the constant of proportionality in the rate equation of the reaction.

(c)(i) Step 1: rate = $k_f[O_3]$
Step 2: rate = $k_2[O_3][O]$

(c)(ii) At equilibrium, rate of forward reaction of step 1 = rate of reverse reaction of step 1
i.e. $k_f[O_3] = k_r[O][O_2]$

$$[O] = \frac{k_f[O_3]}{k_r[O_2]}$$

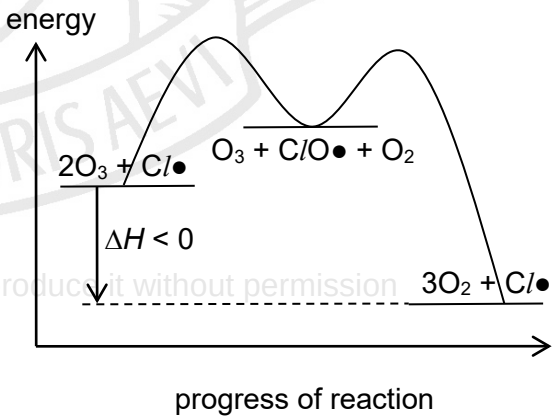
(c)(iii) Since step 2 is the slow step, rate = $k_2[O_3][O]$.
Using expression from (c)(ii),

rate = $k_2[O_3][O] = k_2[O_3] \frac{k_f[O_3]}{k_r[O_2]} = \frac{k_2 k_f[O_3]^2}{k_r[O_2]}$

order of reaction wrt O_3 = 2
order of reaction wrt O_2 = –1
overall order of reaction = 2 + (–1) = 1

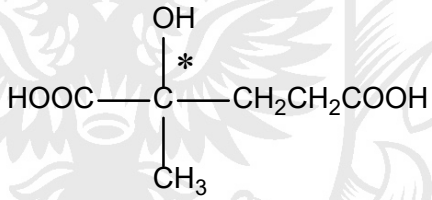
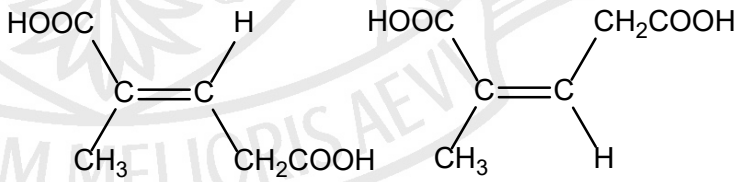
(d)(i) C*l*● is a homogeneous catalyst as it is in the same phase as the reactant, O_3, and is consumed in step 1 and regenerated in step 2.

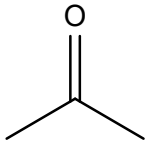
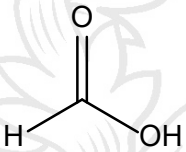
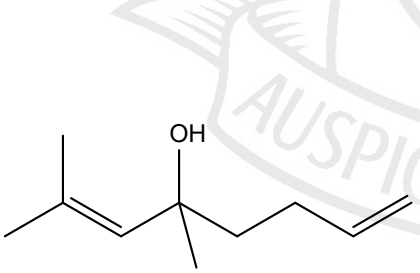
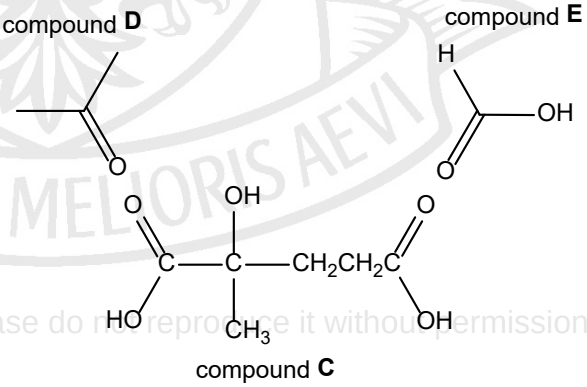
(d)(ii)



(e)(i) Ni acts as a heterogeneous catalyst. Molecules of A and H_2 diffuse and are adsorb onto the surface of the Ni catalyst by forming weak interactions with Ni. This increases the concentration of A and H_2 at the catalytic surface, the reactant molecules are brought closer together with the correct orientation, and the covalent bonds within A and H_2 are weakened which reduces the activation energy for the reaction. A and H_2 then react on the Ni surface before they desorb and diffuse from the surface of the Ni catalyst, regenerating active sites for other A and H_2 molecules.

(e)(ii)

Observations	Deductions
$A(C_{10}H_{18}O) \xrightarrow{\text{excess } H_2} B(C_{10}H_{22}O)$	Type of reaction : Reduction • Gain of 4 H ⇒ A contains 2 unsaturated bonds (C=C or C=O)
$A\ (C_{10}H_{18}O) \xrightarrow{\text{excess } O_3} C\ (C_6H_{10}O_5) + D + E\ (CH_2O_2)$	Type of reaction : Oxidation • A contains 2 C=C since oxidation of A gave 3 products. • D contains 3 carbon atoms.
C, E, F effervesce with $Na_2CO_3(aq)$	Type of reaction : Acid-base reaction • C, E and F contain the –COOH group.
$C\ (C_6H_{10}O_5) \xrightarrow[H_2SO_4]{\text{hot conc}} F\ (C_6H_8O_4)$ 1 chiral centre 0 chiral centre 2 stereoisomers C does not react with $K_2Cr_2O_7$	Type of reaction : Elimination of water • Alcohol in C was eliminated to form C=C in F which exhibits cis-trans isomerism • –OH is on chiral carbon in C • Tertiary alcohol in present C We can deduce the following structures.  compound **C**  compound **F** **Note**: Both stereoisomers should be shown.
D gives yellow ppt with alkaline aq iodine, but does not react with Fehling's reagent.	Type of reaction with alkaline aq iodine : Oxidation (positive iodoform test) • No aldehyde present (negative Fehling's test)

	• D contains 3 carbons (from previous deduction) and $–COCH_3$. The structure of D is as follows.  compound **D**
E (CH_2O_2)	• E contains –COOH (from previous deduction) The structure of E is as follows.  compound **E**
Since A ($C_{10}H_{18}O$) $\xrightarrow{\text{excess } O_3}$ C ($C_6H_{10}O_5$) + D + E (CH_2O_2), possible structures of A are shown below.  compound **A** compound **C**  compound **A**  compound **C**	

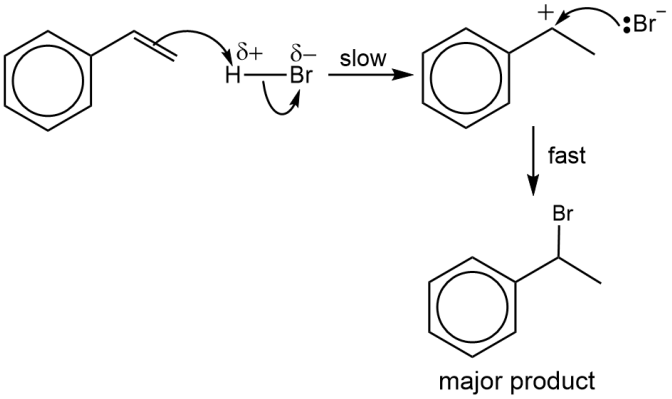
Question 4

(a) Hydrogen chloride is thermally stable (does not decompose). Hydrogen bromide and hydrogen iodide thermally decompose to give hydrogen gas and their respective halogens as shown in the following equation.

$2HX \rightleftharpoons H_2 + X_2$ (where X = Br and I)

Since the bond energy decreases from HCl to H–Br to HI, the bond strength decreases in the same order. **[1]** Thus, the thermal stability of the hydrogen halides decreases from H–Cl to H–Br to H–I.

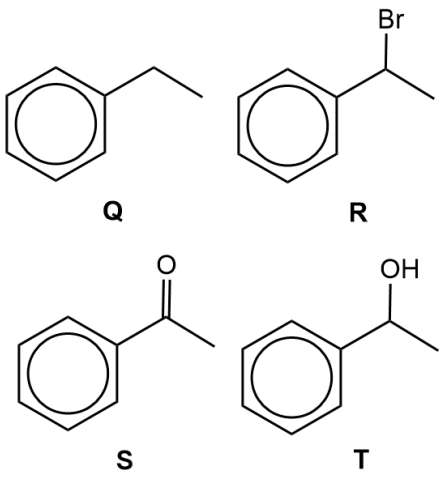
(b)



$C_6H_5\overset{+}{C}HCH_3$ is a more stable carbocation than $C_6H_5CH_2\overset{+}{C}H_2$ because it is resonance stabilised. In $C_6H_5\overset{+}{C}HCH_3$ the empty p-orbital of the positively charged carbon overlaps with the π electron cloud of benzene, allowing the π electrons of benzene to delocalize onto the empty p orbital of the positively charged carbon, dispersing the positive charge.

Hence, in the slow step, the more stable 2° carbocation ($C_6H_5\overset{+}{C}HCH_3$) is formed, instead of the less stable 1° carbocation ($C_6H_5CH_2\overset{+}{C}H_2$), which dispersed the positive charge to a greater extent. The 2° carbocation then undergoes reaction with Br^- in the fast step to form the major product.

(c)(i)



(c)(ii) step 1 : CH_3CH_2Cl, $AlCl_3$ (or $FeCl_3$)
step 2 : limited Br_2, UV
step 3 : ethanolic KOH, heat

step II : $NaBH_4$ or $LiAlH_4$ in dry ether
or H_2, Ni, heat
step III : excess concentrated H_2SO_4, heat

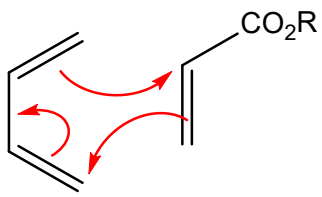
(d) Isomer 4-position will be formed the most.
Isomer 3-position will be formed the least.

The carbocation intermediates leading to isomer 2-position and isomer 4-position are tertiary carbocations, which have 3 electron-donating alkyl groups attached to the C^+, which stabilise these carbocations to a greater extent than the secondary carbocation leading to isomer 3-position. Thus, isomer 2-position and isomer 4-position are preferred over isomer 3-position.

The carbocation leading to isomer 2-position has the bulky $–C(CH_3)_3$ group in close proximity to the $–NO_2$ group, causing steric hindrance / additional repulsion between the two groups, which destablilises the carbocation more than in the case of the carbocation leading to isomer 4-position which have the bulky $–C(CH_3)_3$ group far away from the $–NO_2$ group. Thus, isomer

4-position is preferred over isomer 2-position.

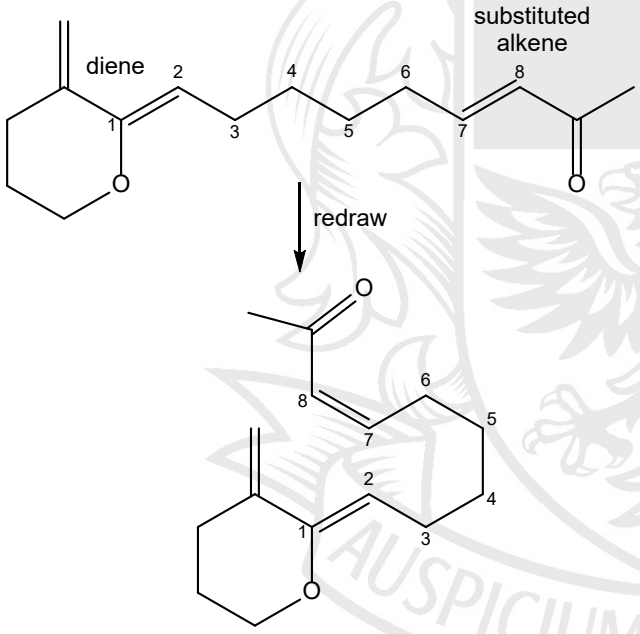
(e)(i)

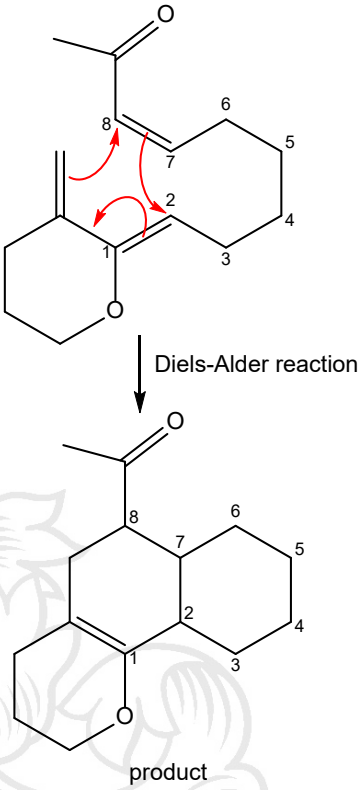


(e)(ii) The diene can attack the substituted alkene from above or below the plane of the planar alkene of the substituted alkene with equal probability, forming a 1:1 mixture of enantiomers of **X**, causing **X** to have no effect on the plane of polarised light.

(e)(iii) **Note**:

1. Start by redrawing **W** to position the diene and substituted alkene in closer proximity similar to what you see in Fig. 4.3.
2. Numbering the carbons on long chains is a strategy to make sure all carbons atoms are accounted for and not "lost" due to carelessness.





Question 5

(a) $CO_3^{2-} \longrightarrow CO_2 + O^{2-}$

Down group 2, the cationic radius increases, resulting in a lower charge density and weaker polarising power of the cations. Consequently, there is decreasing extent of distortion of the electron cloud of the CO_3^{2-} anion and hence decreasing extent of weakening of covalent bonds within the CO_3^{2-} anion. More heat energy is required to break the covalent bonds within the CO_3^{2-} anion, causing the decomposition temperature to increase. Hence, thermal stability of the Group 2 carbonates increases.

(b)(i) **(1)** – $H_2C_2O_4 \longrightarrow 2CO_2 + 2H^+ + 2e^-$

(2) – $MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$

5 x (1) + 2 x (2) :

$5H_2C_2O_4 + 2MnO_4^- + 6H^+ \longrightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$

(b)(ii) amount of MnO_4^- = $(\frac{22.4}{1000})(0.001)$
= 2.24 x 10^{-5} mol

amount of $H_2C_2O_4$ = $\frac{5}{2}(2.24 \times 10^{-5})$
= 5.60 x 10^{-5} mol

$CaC_2O_4 + 2H^+ \longrightarrow H_2C_2O_4 + Ca^{2+}$

amount of CaC_2O_4 = 5.60 x 10^{-5} mol
= amount of Ca^{2+} in blood

mass of Ca^{2+} in blood = $(5.60 \times 10^{-5})(40.1)$
= 0.002246 g
= 2.25 x 10^{-3} g
= 2.25 mg

(b)(iii) **Note:** since R is 8.31 **J** mol^{-1} K^{-1}, $\Delta G^{\ominus}$ needs to be convert to J mol^{-1} when using the given equation.

$K_{sp} = 10^{-\frac{49200}{8.31(298)(2.3)}}$
= 2.30 x 10^{-9} mol^2 dm^{-6}

(c)(i) $pH = pK_a + lg\frac{[CH_3CH(OH)CO_2^-]}{[CH_3CH(OH)CO_2H]}$

$6.50 = -lg(1.38 \times 10^{-4}) + lg\frac{0.028}{[CH_3CH(OH)CO_2H]}$

$[CH_3CH(OH)CO_2H]$
= 6.42 x 10^{-5} mol dm^{-3}

(c)(ii) $K_c = \frac{[CH_3CH(OH)COO^-][H_2NCONH_3^+]}{[CH_3CH(OH)COOH][H_2NCONH_2]}$
= 1.74 x 10^{-4} --- **(1)**

$K_a = \frac{[CH_3CH(OH)COO^-][H^+]}{[CH_3CH(OH)COOH]}$
= 1.38 x 10^{-4} --- **(2)**

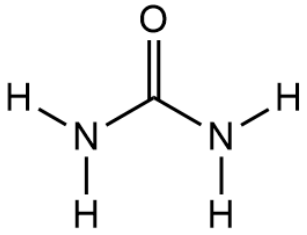
$\frac{(1)}{(2)}$
$= \frac{[CH_3CH(OH)COO^-][H_2NCONH_3^+]}{[CH_3CH(OH)COOH][H_2NCONH_2]} \times \frac{[CH_3CH(OH)COOH]}{[CH_3CH(OH)COO^-][H^+]}$
$= \frac{[H_2NCONH_3^+]}{[H_2NCONH_2][H^+]}$ = 1.26 **--- (3)**

K_b of urea = $\frac{[H_2NCONH_3^+][OH^-]}{[H_2NCONH_2]}$

Comparing **(3)** and K_b of urea and since $K_w = [H^+][OH^-]$,

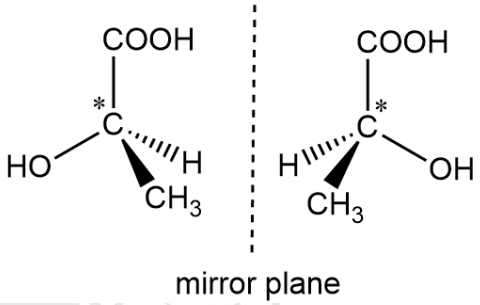
K_b of urea = **(3)** x K_w
= 1.26 x 10^{-14} mol dm^{-3}

(c)(iii) Urea (H_2NCONH_2) has the following structure.

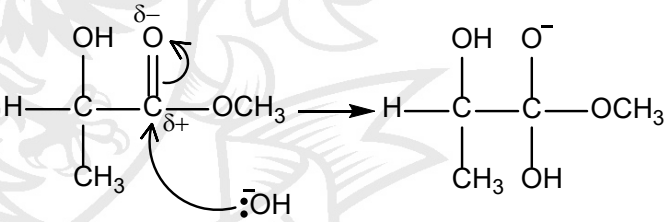


No. of σ-bonds = 7
No. of π-bonds = 1

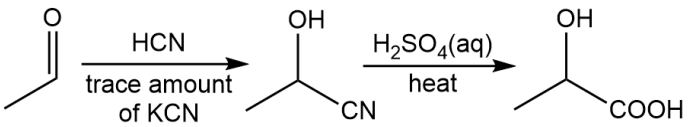
(d)(i) Lactic acid has a chiral centre and displays enantiomerism.



(d)(ii) **Note**: students need to draw from their knowledge of how a nucleophile attacks a C=O from the topic of *Carbonyl Compounds*.

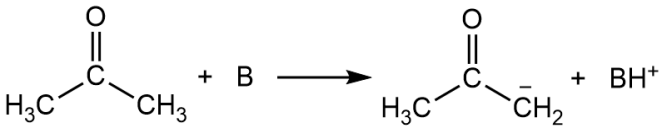


(e)

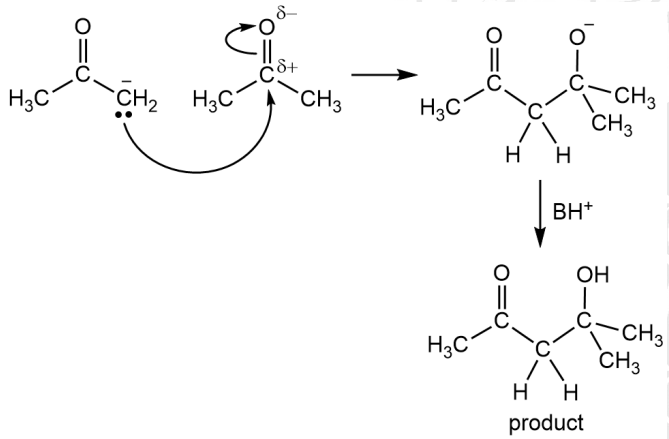


(f)(i) **Note**: it is important to learn from the information provided in the question stem and equations.

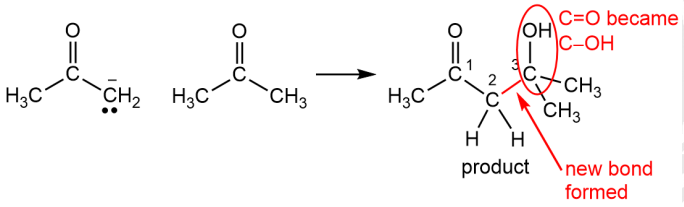
Since the H bonded to a C adjacent to carbonyl can be removed by a base,



The anion acts as a nucleophile and reacts with the carbonyl group of another propanone.

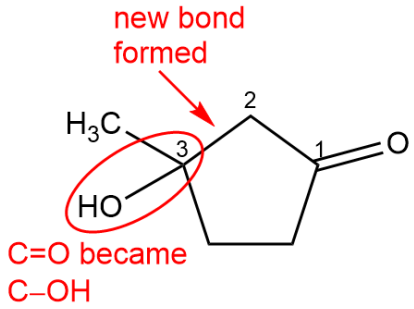


(f)(ii) **Note:** using (f)(i) as an example, you can identify the changes that occur during the reaction.



1. The 2 original carbonyl carbons are three carbons apart in the final product.
2. Location of new bond formed.
3. C=O became C–OH

Applying this analysis to **Z.**



Working backwards you will obtain **Y** as