

Section A

Answer all questions in the spaces provided.

- 1 Elements A, B, C, D and E are five consecutive elements from Period 3 and 4 of the Periodic Table. The table below shows the 1st eight ionisation energies for element C.

| No. of electrons removed | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--|------|------|------|------|------|------|-------|-------|
| Ionisation energy / kJ mol ⁻¹ | 1260 | 2300 | 3850 | 5150 | 6542 | 9362 | 11018 | 33604 |

- (a) (i) Deduce and explain which group element C comes from.

Group VII. Largest jump in ionisation energy from 7th to 8th electron. Thus, there are 7 valence electrons. The 8th electron is located in an inner principal quantum shell nearer the nucleus, thus experience greater attraction, requiring much more energy to remove.

- (ii) Hence deduce the identity of element C and write down its electronic configuration.

Chlorine. Electronic configuration: $1s^2 2s^2 2p^6 3s^2 3p^5$.

[4]

- (b) Explain the following observations.

- (i) The first ionisation energy of element B is lower than the first ionisation energy of element A even though the effective nuclear charge of element B is higher than the effective nuclear charge of element A.

B is sulfur: $[\text{Ne}]3s^2 3p^4$, A is phosphorus: $[\text{Ne}]3s^2 3p^3$

In B, there is inter-electronic repulsion between the paired electrons in the same p-orbital, thus the most loosely held electron of B require less energy to be removed than in A.

- (ii) The atomic radius of element D is smaller than the atomic radius of element E.

D is Ar, E is K

Valence electrons of D occupy a lower principal quantum shell nearer the nucleus, thus the valence electrons experience greater attraction to the nucleus compared to in E resulting in a smaller atomic radius.

or

Valence electrons of E occupy a higher principal quantum shell further to the nucleus, thus the valence electrons experience less attraction to the nucleus, resulting in a smaller atomic radius.

- (iii) The ionic radius of the ion formed by the element C is larger than the ionic radius of the ion formed by the element E even though both of the ions are isoelectronic.

The ion of E has more protons, thus higher nuclear charge than the ion of C, but number of electrons is the same. This causes the stronger electrostatic

attraction between the nucleus and the valence electrons resulting in a smaller ionic radius of E.

or

The ion of C has less protons, thus lower nuclear charge than the ion of E, but number of electrons is the same. This causes the weaker electrostatic attraction between the nucleus and the valence electrons resulting in a larger ionic radius of C.

[6]

[Total: 10]

2 Chlorine and its compounds are applied in a variety of chemical reactions.

(a) Chlorine reacts with benzene, cyclohexene and cyclohexane under different conditions.

(i) State the respective reaction conditions for chlorine to react with each of the organic compounds.

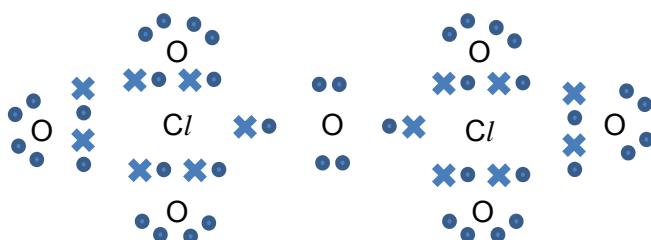
| | |
|------------------|--|
| With benzene | Chlorine in $AlCl_3$, $FeCl_3$, or Fe catalyst |
| With cyclohexene | Chlorine in CCl_4 or $Cl_2(aq)$ (at r.t.) |
| With cyclohexane | Chlorine in the presence of UV light |

(ii) Hence, deduce the order of reactivity for benzene, cyclohexene and cyclohexane.

In order of increasing reactivity Benzene, Cyclohexane, Cyclohexene

[3]

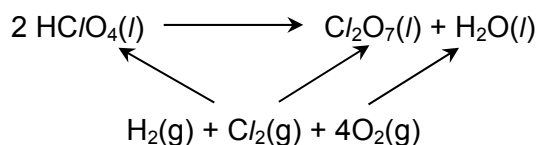
(b) The most stable oxide of chlorine is dichlorine heptoxide. It has the formula Cl_2O_7 and contains a $Cl-O-Cl$ linkage. Draw the dot-and-cross diagram for dichlorine heptoxide, stating the shape with respect to each central atom.



Tetrahedral about Cl, Bent about O

[2]

(c) Dichlorine heptoxide is formed from the dehydration of perchloric acid, $HClO_4$. As both reactants and products are unstable, the standard enthalpy change of reaction, ΔH^θ_{rxn} , can only be obtained through theoretical calculations.



$$\Delta H_f^\theta(\text{HClO}_4) = -6.3 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\theta(\text{Cl}_2\text{O}_7) = -135 \text{ kJ mol}^{-1}$$

$$\Delta H_c^\theta(\text{H}_2) = -286 \text{ kJ mol}^{-1}$$

- (i) Define the term standard enthalpy change of formation of dichlorine heptoxide.

The standard enthalpy change of formation of dichlorine heptoxide is the energy change when one mole of the dichlorine heptoxide is formed from its constituent elements, H_2 , Cl_2 and O_2 , under standard conditions.

- (ii) With reference to the energy cycle and data provided, calculate the standard enthalpy change of reaction, $\Delta H_{\text{rxn}}^\theta$.

By Hess' Law,

$$\begin{aligned}
 \Delta H_{\text{rxn}} &= -2\Delta H_f^\theta(\text{HClO}_4) + \Delta H_f^\theta(\text{Cl}_2\text{O}_7) + \Delta H_c^\theta(\text{H}_2) \\
 &= -2(-6.3) + (-135) + (-286) \\
 &= -408.4 \text{ kJ mol}^{-1} = -408 \text{ kJ mol}^{-1} \text{ (3sf)}
 \end{aligned}$$

[3]

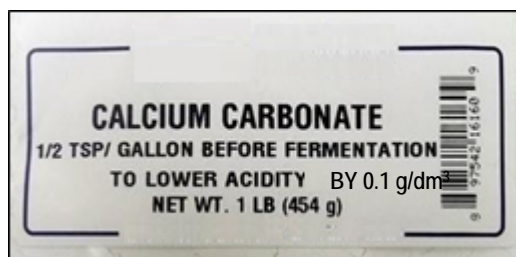
[Total: 8]

- 3 Wine is a complex mixture of chemicals which contribute to the acidity, taste, colour and texture of the wine. During the making of wine, the acidity of wine, which is also measured in terms of pH, is carefully controlled as it affects both the fermentation process and the wine's final taste.

Each type of wine has a different level of acidity. In order to obtain a fermentation mixture with the appropriate pH, home winemakers often need to refer to recommended levels of "*titratable acidity (TA)*", which calculates the mass of acid in a fixed volume of wine by assuming that tartaric acid is the only acid present in wine. The following table shows the recommended TA for two types of wine.

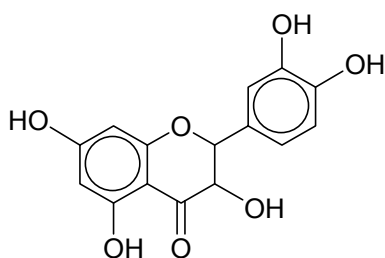
| wine style | recommended titratable acidity (g dm^{-3}) | pH range |
|----------------|---|-------------|
| dry white wine | 6.5 – 7.5 | 2.11 – 2.16 |
| sherry | 5.0 – 6.0 | 2.16 – 2.20 |

One reliable method to determine the TA of wine is to perform titration of a small wine sample with aqueous sodium hydroxide. If the TA is found to be above the recommended range for a desired wine type, calcium carbonate can be added as an additive. The label below shows the calcium carbonate sold online by wine making websites.

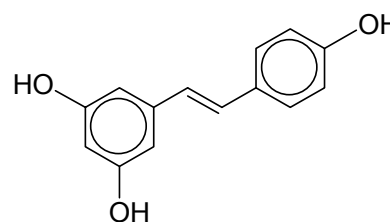


(1/2 TSP contains 2.85 g of calcium carbonate; 1 gallon = 3.8 dm³)

Some of the chemicals in wine also act as buffers and thus regulate acidity. Examples include resveratrol and quercetin, whose structures are shown below. As many of such chemicals are found in the skins of red grapes, red wine is found to have a “larger buffering capacity” compared to white wine.



quercetin

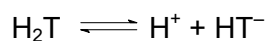


resveratrol

- (a) (i) Define pH.

$$\text{pH} = -\log_{10}[\text{H}^+]$$

- (ii) By using H₂T as the symbol for tartaric acid, write the equilibrium which represents the dissociation of the first proton. Write an expression for the acid dissociation constant, K_a , for your chosen equilibrium.



$$K_a = \frac{[\text{H}^+][\text{HT}^-]}{[\text{H}_2\text{T}]}$$

- (iii) With reference to the table above, calculate the minimum concentration, in mol dm⁻³, of tartaric acid and hydrogen ions recommended in sherry.

M_r of tartaric acid = 150.0

Minimum concentration of tartaric acid in sherry

$$= \frac{5.0}{150.0} = 0.0333 \text{ mol dm}^{-3}$$

Minimum concentration of protons in sherry

$$= 10^{-2.2} = 0.006309 = 0.00631 \text{ mol dm}^{-3}$$

- (iv) Hence, deduce the acid dissociation constant, K_a , of tartaric acid.

$$K_a = \frac{[\text{H}^+]^2}{[\text{H}_2\text{T}]} = \frac{0.006309^2}{0.0333} = 1.19 \times 10^{-3} \text{ mol dm}^{-3}$$

[5]

- (b) Suggest with explanations, a suitable indicator for the titration between wine and sodium hydroxide.

Phenolphthalein is a suitable indicator. The pH transition range of phenolphthalein lies within the rapid pH change over the equivalence point of this titration.

[2]

- (c) A home wine maker prepared 20 dm³ of fermentation mixture for dry white wine and found that the TA was 7.8. Using the data on page 6, calculate the minimum mass of online purchased calcium carbonate required to obtain a suitable mixture for dry white wine.

From the data:

2.85 g of solute reduces the TA of 3.8 dm³ by 0.1

Mass of solute required to reduce 3.8 dm³ by 0.3 = 2.85 × 3 = 8.55 g

Mass of solute required to reduce 20 dm³ by 0.3 = $\frac{8.55}{3.8} \times 20 = 45$ g

[2]

- (d) (i) On the structure of quercetin on page 6, name and circle two different functional groups.

Name and circle any 2 of the following
Phenol, ketone, secondary alcohol, ether

- (ii) Given that resveratrol is weakly acidic, write equations to illustrate how a buffer solution of resveratrol (represented as HA) and its sodium salt (represented as Na⁺A⁻) regulates acidity.

When H⁺ ions are added $H^+ + A^- \rightarrow HA$

When OH⁻ ions are added $OH^- + HA \rightarrow A^- + H_2O$

- (iii) Suggest what it means for red wine to have a "larger buffering capacity".

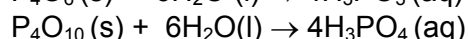
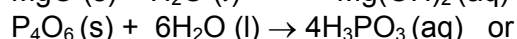
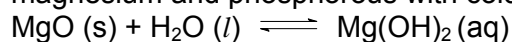
Red wine can react with more added H⁺ or OH⁻ without a change in pH. or Red wine contains a larger concentration of acids and a larger amount of the salts of its conjugate base, to resist pH changes when H⁺ or OH⁻ is added.

[3]

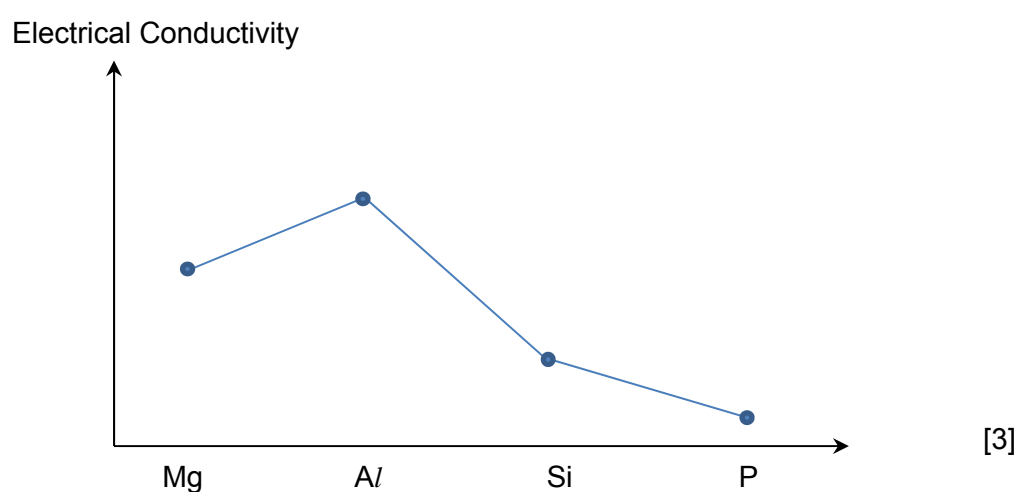
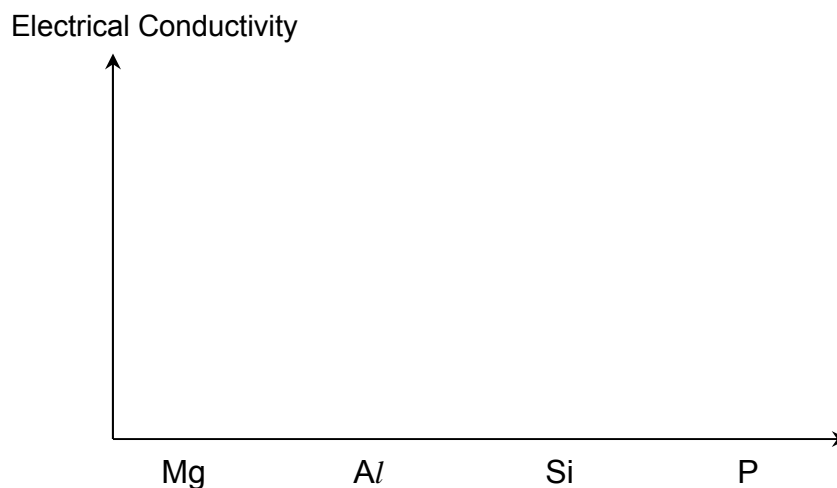
[Total: 12]

- 4 Magnesium, the fourth most abundant element on Earth, has diverse applications such as in building or medicine.

- (a) (i) Write equations, with state symbols, for the reactions of the oxides of magnesium and phosphorous with cold water.



- (ii) On the axes below, sketch the electrical conductivity of the period 3 elements from magnesium to phosphorous.



- (b) Constipation medicine, containing magnesium, is available in tablet or powder containing capsule forms as shown below.



Tablet



Powder Containing Capsule

Suggest, with explanations, which form would faster relieve the symptoms of constipation.

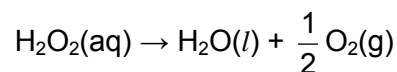
The powder containing capsule form would faster relieve the symptoms of constipation.

Powdered medicine has a greater surface area compared to tablets. Hence, the accessible area for collision increases. Frequency of effective collisions with $E \geq E_a$ taking place in the reaction increases. Since rate of reaction is proportional to the frequency of effective collisions, rate of reaction increases.

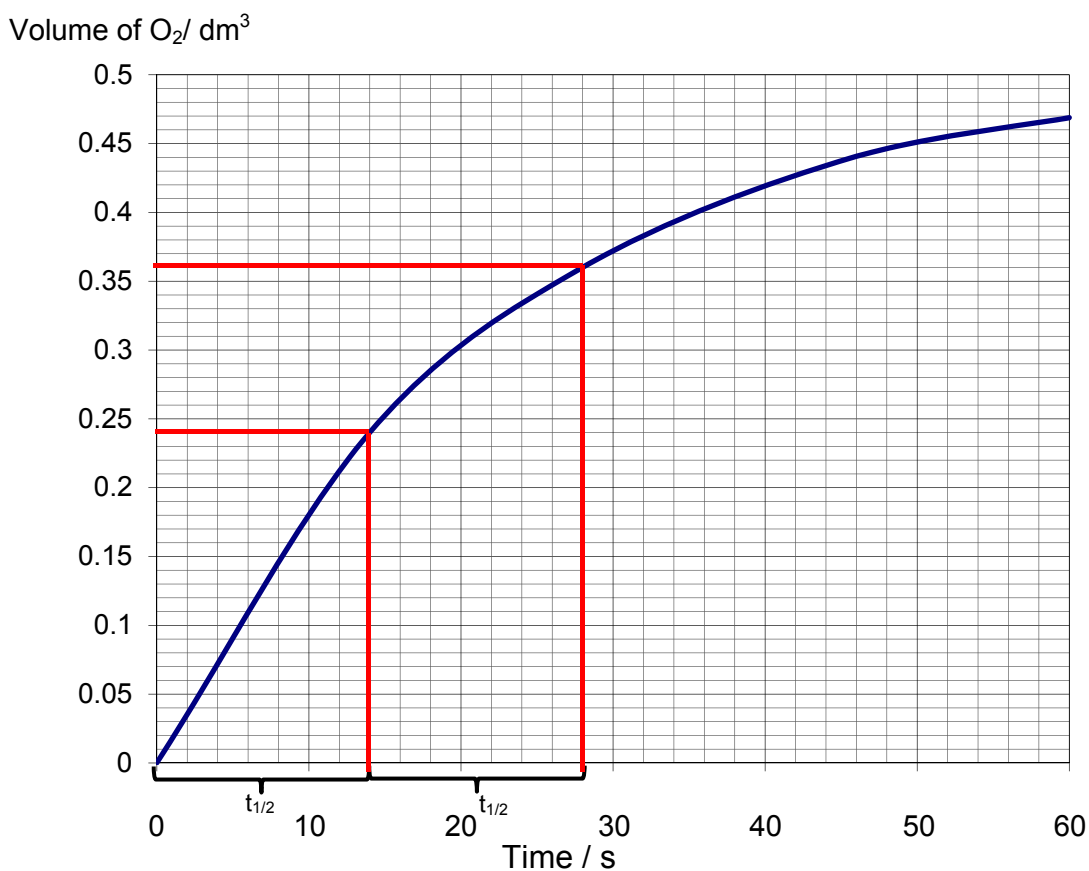
[2]

5 Hydrogen peroxide solution can be used to bleach hair.

A solution of hydrogen peroxide slowly in aqueous solution according to the following equation.



A 50 cm³ solution with the original concentration of 0.8 mol dm⁻³ was placed in a bottle contaminated with transition metal ions, which act as catalysts for the decomposition. The volume of oxygen produced was collected over time, and the following graph was obtained at room conditions.



- (a) Complete the following table to determine the volume of oxygen produced when the concentration of hydrogen peroxide has been reduced to 50% and to 25% of original concentration.

| percentage of original [H ₂ O ₂] left | no. of moles of H ₂ O ₂ reacted | volume of oxygen produced / dm ³ |
|--|---|---|
| 50% | $0.8 \times \frac{50}{1000} \times 0.50$ = 0.02 | $0.02 \times \frac{1}{2} \times 24$ = 0.24 |
| 25% | $0.8 \times \frac{50}{1000} \times 0.75$ = 0.03 | $0.03 \times \frac{1}{2} \times 24$ = 0.36 |

[2]

- (b) Using the graph and information from (a), deduce the order with respect to

hydrogen peroxide.

From the graph, half-life is constant at 14 seconds.

Thus order of reaction with respect to hydrogen peroxide is one.

[2]

- (c) Given that the gradient at 0 seconds is $0.0125 \text{ mol dm}^{-3} \text{ s}^{-1}$, calculate a value for the rate constant.

$$\text{rate} = k[\text{H}_2\text{O}_2]$$

$$0.0125 = k(0.8)$$

$$k = \frac{0.0125}{0.8} = 0.01562 = 0.0156 \text{ s}^{-1} \text{ (3s.f.)}$$

[1]

[Total: 5]

Section B

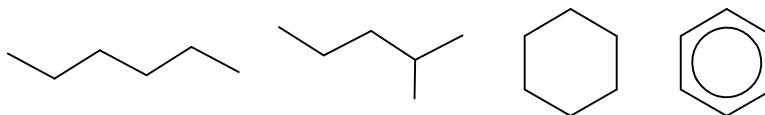
Answer any two questions from this section on separate answer paper.

- 6 (a) The ExxonMobil's Singapore Refinery, its largest refinery in the world, owns and operates a 605,000-barrel-per-day refinery in Jurong and on Jurong Island. The refinery operating on the Jurong Island converts crude oil into finished products such as liquefied petroleum gas and motor gasoline among many other products.

Gasoline, commonly known as petrol in Singapore, is a complex mixture of hydrocarbon that may contain 500 hydrocarbons between 5 – 12 carbons. A typical composition of gasoline is as follows:

| <i>type of hydrocarbon</i> | <i>Percentage in mixture</i> |
|----------------------------|------------------------------|
| Straight chain alkanes | 30% |
| Branched chain alkanes | 30% |
| Cyclic alkanes | 20% |
| Benzenes | 20% |

- (i) For each of the four types of hydrocarbon, draw the structural formula of a representative 6-carbon hydrocarbon.



- (ii) What would be the mass of a gasoline mixture containing 500 6-carbon hydrocarbons?

Straight chain & branched chain alkane: C_6H_{14}

Cyclic alkanes: C_6H_{12}

Benzenes: C_6H_6

$$\text{Mass} = 60\%(500)(86) + 20\%(500)(84) + 20\%(500)(78) = 42000 \text{ g}$$

[4]

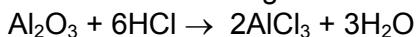
- (b) A Japanese company claimed to have created a nanotechnology powered fuel-saving catalyst called "Nanoballs". This catalyst is said to enable gasoline to burn more efficiently and cleanly. One main component of Nanoballs is aluminium silicate which is essentially aluminium oxide and silicon dioxide.

- (i) Describe the structure and bonding in aluminium oxide and silicon dioxide.

Al_2O_3 is a giant ionic compound with ionic bonding / electrostatic forces of attraction between oppositely charged Al^{3+} and O^{2-} ions.

SiO_2 is a giant molecular compound with covalent bonds between Si and O atoms in a 3-dimensional network

- (ii) With the use of a balanced chemical equation, identify one reagent that can be used to distinguish between aluminium oxide and silicon dioxide.



- (c) The Jurong Aromatics Plant on Jurong Island produces cyclohexane used in making nylon and to manufacture end products such as textile, carpets and auto parts. A sample of cyclohexane and its reaction with bromine is studied. [3]

Bromine is added to an excess of cyclohexane (C_6H_{12}) and water. A shot of ultraviolet light is then given to this mixture. When the reaction is complete, the resultant aqueous layer contains hydrobromic acid (HBr).

It is found that 25 cm^3 of $0.100 \text{ mol dm}^{-3}$ solution of aqueous sodium hydroxide is required to neutralise all the acid in the aqueous layer.

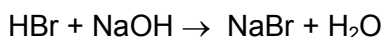
- (i) Identify the type of reaction that has occurred between cyclohexane and bromine.

(Free Radical) Substitution

- (ii) How can you tell that the reaction is complete?

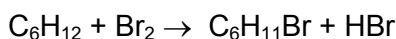
Reddish-brown bromine is decolourised.

- (iii) Determine the number of moles of HBr present.



$$\text{No. of moles of HBr} = \text{No. of moles of NaOH} = 25/1000 \times 0.100 = 2.50 \times 10^{-3}$$

- (iv) Assuming that the main organic product of this reaction is bromocyclohexane, write a balanced equation for the reaction and determine the number of moles of cyclohexane that has reacted.



$$\text{No. of moles of C}_6\text{H}_{12} = \text{no. of moles of HBr} = 2.50 \times 10^{-3}$$

[6]

- (d) To test for the presence of bromocyclohexane, aqueous sodium hydroxide is added to bromocyclohexane and heated. Reagent F followed by reagent G is then added to the resulting solution. A large amount of precipitate is observed.

- (i) Identify the type of reaction that has occurred between bromocyclohexane and aqueous sodium hydroxide.

(Nucleophilic) Substitution

(ii) Identify reagents F, G and the precipitate.

F: dilute HNO_3
G: aqueous AgNO_3
ppt: AgBr

(iii) The reaction in (i) is found to be overall second order, involving both reactants in a one-step reaction. Write the rate equation for this reaction.

$$\text{Rate} = k[\text{OH}^-][\text{C}_6\text{H}_{11}\text{Br}]$$

(iv) Predict with reasoning how the rate would be affected if the concentration of both reactants is doubled.

Since reaction is overall 2nd order, rate will be increased by $2^2 = 4$ times.

Or

If original rate is R,

doubling $[\text{OH}^-]$ will double rate to 2R

doubling $[\text{C}_6\text{H}_{11}\text{Br}]$ will double 2R to 4R \Rightarrow rate increases 4 times.

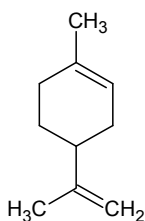
(v) When chlorocyclohexane is used instead of bromocyclohexane in the reaction with aqueous sodium hydroxide under similar conditions, it is found that the precipitate appears more slowly. Explain this difference.

C–Cl bond is shorter than C–Br bond and hence it is stronger / has higher bond energy. More energy is required to break the C–Cl bond and hence under the same condition, product is formed at a slower rate.

[7]

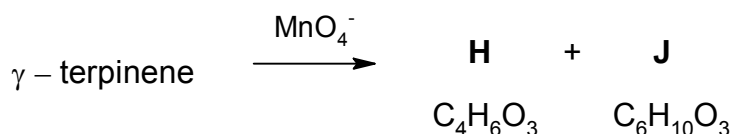
[Total: 20]

7 Limonene, $\text{C}_{10}\text{H}_{16}$, is a cyclic terpene which possesses a strong smell of lemon.



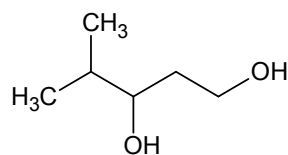
Limonene

(a) γ -Terpinene is an isomer of limonene. On treatment with an excess of hot concentrated manganate(VII) ions it forms two products H and J.



Both compounds H and J evolve CO_2 with $\text{Na}_2\text{CO}_3(\text{aq})$ and both give orange precipitates with 2,4 – dinitrophenylhydrazine reagent, but neither reacts with Fehling's

solution. Compound H gives a yellow precipitate with alkaline aqueous iodine, but J does not. Compound J can be obtained from compound K by reaction with hot acidified $\text{Cr}_2\text{O}_7^{2-}$ ions.



K

Use the information above to deduce the structures for γ -terpinene, compound H and J, explaining all the reactions involved.

γ -Terpinene undergoes oxidation/oxidative cleavage with hot concentrated manganate(VII) ions

Compounds H and J undergo neutralisation with $\text{Na}_2\text{CO}_3(\text{aq})$

\Rightarrow Both compounds H and J are carboxylic acids.

Compounds H and J undergo condensation with 2,4-dinitrophenylhydrazine.

\Rightarrow Both compounds H and J are carbonyl compounds.

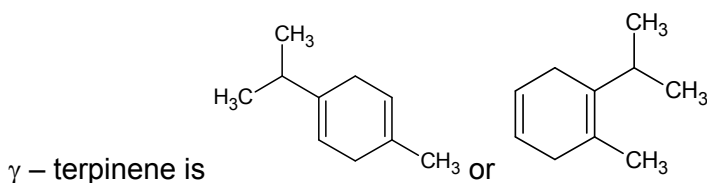
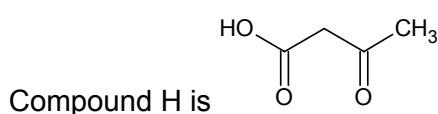
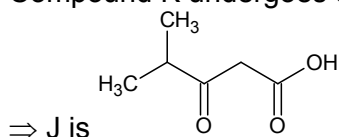
Compounds H and J do NOT undergo oxidation with Fehling's solution.

\Rightarrow Both compounds H and J are NOT aldehydes.

Compound H undergo oxidation with alkaline aqueous iodine solution.

\Rightarrow compound H contains

Compound K undergoes oxidation with $\text{Cr}_2\text{O}_7^{2-}$ ions to form J.



[12]

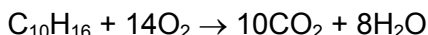
(b) Because of its ready availability, surplus limonene has been used as a biofuel in diesel engines.

(i) Define the term *standard enthalpy change of combustion* of limonene.

The *standard enthalpy change of combustion* of limonene is the energy evolved when one mole of limonene is completely combusted under standard

conditions.

- (ii) Using the molecular formula of limonene, write a balanced equation for the complete combustion in air.



- (iii) Use bond energy values from the *Data Booklet* to calculate the enthalpy change of combustion of limonene. [Rather than the C=O value given in the *Data Booklet*, use a value of 805 KJ mol⁻¹ for the bond energy of each C=O bond in CO₂.]

ΔH_c (limonene)

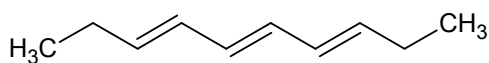
$$= [16 \times 410 + 8 \times 350 + 2 \times 610 + 14 \times 496] - [20 \times 805 + 16 \times 460]$$
$$= -5936 \text{ kJ mol}^{-1} = -5.94 \times 10^3 \text{ kJ mol}^{-1} \text{ (3s.f.)}$$

- (iv) The enthalpy change of combustion of conventional diesel fuel is about -45 KJ g⁻¹. How does the enthalpy change of combustion of limonene per gram compare to this value?

$$\Delta H_c \text{ (limonene)} = \frac{-5936}{120 + 16} = -43.6 \text{ kJ g}^{-1} \text{ (3sf)}$$

The enthalpy change of combustion of limonene per gram is less exothermic than that of conventional diesel fuel.

- (v) Deca-3,5,7-triene is another isomer of limonene. Explain, in terms of bonding and structure of both limonene and deca-3,5,7-triene, which compound should have a higher boiling point.



deca-3,5,7-triene

Both deca-3,5,7-triene and limonene are expected to be simple molecular structures. Both compounds are held by intermolecular temporary dipole – temporary dipole interactions. However, limonene being a more compact and spherical molecule, would be expected to have lower extent of temporary dipole – temporary dipole interactions than the straight chain deca-3,5,7-triene. Hence, deca-3,5,7-triene is expected to have a higher boiling point.

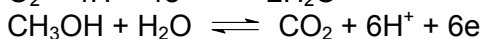
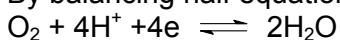
[8]

[Total: 20]

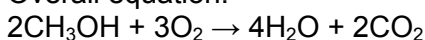
- 8 Methanol, a highly toxic liquid, has a variety of applications in fuel cells and organic synthesis, among many others.

- (a) When methanol is used as a fuel cell, it is oxidised to carbon dioxide. The oxidising agent, oxygen, is converted to water.

- (i) By balancing half equations, write the overall equation for the reaction above.



Overall equation:



- (ii) In an experiment, 350 cm³ of 1.5 mol dm⁻³ methanol is reacted. Given that the

percentage of oxygen in air is 20%, calculate the minimum volume of air required, at room temperature and pressure, to completely react with the methanol present.

$$\text{No. of moles of methanol present} = \frac{350}{1000} \times 1.5 = 0.525 \text{ mol}$$

$$\text{No. of moles of oxygen required to react} = \frac{0.525}{2} \times 3 = 0.7875 \text{ mol}$$

$$\text{Volume of oxygen required} = 0.7875 \times 24 = 18.9 \text{ dm}^3$$

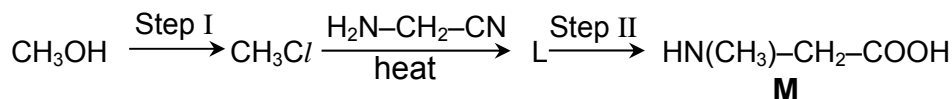
$$\text{Volume of air required} = \frac{18.9}{0.2} = 94.5 \text{ dm}^3$$

- (iii) Suggest suitable reagents and conditions to convert methanol to carbon dioxide in an organic laboratory.

Acidified KMnO_4 , reflux

[5]

- (b) Methanol can be converted into product M in the following three step synthesis.



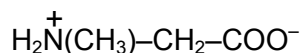
- (i) Deduce the identity of L, and suggest suitable reagents and conditions for Steps I and II.

L : $\text{HN}(\text{CH}_3)-\text{CH}_2-\text{CN}$

Steps I : PCl_3 or PCl_5 or HCl with ZnCl_2 or SOCl_2

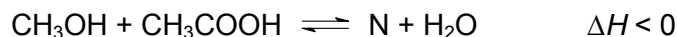
Steps II : aqueous H_2SO_4 , heat

- (ii) In product M, the nitrogen atom is acting as a Bronsted base, and the carboxylic acid acts as a Bronsted acid. Suggest a possible product when product M undergoes an intramolecular neutralisation.



[4]

- (c) Methanol and ethanoic acid react as shown in the following equilibrium.



- (i) A teacher mixed 0.5 mol of CH_3OH and 0.5 mol of ethanoic acid in 1 dm^3 of a suitable solvent and allowed the system to react. After some time, he found that the yield of N remained constant at 60%. Calculate a value of the K_c for this reaction, including units.

$$\text{Number of moles of N at equilibrium} = 0.6 \times 0.5 = 0.3 \text{ moles}$$

| $\text{CH}_3\text{OH} + \text{CH}_3\text{COOH} \rightleftharpoons \text{N} + \text{H}_2\text{O}$ | | | | |
|--|------|------|------|------|
| Initial mol | 0.5 | 0.5 | 0 | 0 |
| Change in mol | -0.3 | -0.3 | +0.3 | +0.3 |
| Eqm mol | 0.2 | 0.2 | 0.3 | 0.3 |

$$K_c = \frac{[\text{C}][\text{H}_2\text{O}]}{[\text{CH}_3\text{OH}][\text{CH}_3\text{COOH}]} = \frac{(0.3)(0.3)}{(0.2)(0.2)} = 2.25$$

- (ii) Hence, deduce the initial amount of methanol required to react with 1.5 mol of ethanoic acid, to produce the same amount of N in (i).
Let the initial amount of methanol required be x mol.

$$\text{CH}_3\text{OH} + \text{CH}_3\text{COOH} \rightleftharpoons \text{N} + \text{H}_2\text{O}$$

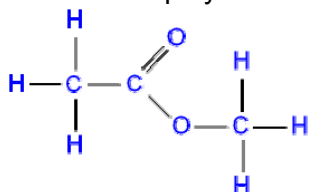
| | | | | |
|---------------|-----------|------|------|------|
| Initial mol | x | 1.5 | 0 | 0 |
| Change in mol | -0.3 | -0.3 | +0.3 | +0.3 |
| Eqm mol | $x - 0.3$ | 1.2 | 0.3 | 0.3 |

$$K_c = \frac{[\text{C}][\text{H}_2\text{O}]}{[\text{CH}_3\text{OH}][\text{CH}_3\text{COOH}]}$$

$$2.25 = \frac{(0.3)^2}{(x - 0.3)(1.2)}$$

$$x = 0.333 \text{ mol}$$

- (iii) Deduce if an increase or decrease in temperature will improve the yield of product N.
A decrease in temperature would improve the yield of product N. As the reaction is exothermic, by Le Chatelier's Principle, when temperature decreases, equilibrium shifts right to increase the heat.
- (iv) State and explain the relative acidity of methanol and ethanoic acid.
Ethanoic acid is more acidic than methanol. The conjugate base of ethanoic acid is stabilised as the negative charge is dispersed over two oxygen atoms.
- (v) Draw the displayed formula of product N.



- (vi) Write a balanced equation for the reaction when N is heated with aqueous sodium hydroxide. State the type of reaction that has taken place.
 $\text{CH}_3\text{COOCH}_3 + \text{NaOH} \rightarrow \text{CH}_3\text{COO}^-\text{Na}^+ + \text{CH}_3\text{OH}$
Hydrolysis

[11]
[Total: 20]