



MINISTRY OF EDUCATION, SINGAPORE in collaboration with UNIVERSITY OF CAMBRIDGE LOCAL EXAMINATIONS SYNDICATE General Certificate of Education Advanced Level Higher 1

	CANDIDATE NAME		
	CENTRE NUMBER	S	INDEX NUMBER
	CHEMIST	RY	8873/02
	Paper 2 Structured Questions		October/November 2019 2 hours

Candidates answer on the Question Paper. Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name on all the work you hand in. Write in dark blue or black pen. You may use an HB pencil for any diagrams or graphs. Do not use staples, paper clips, glue or correction fluid. DO NOT WRITE IN ANY BARCODES.

Section A Answer all the questions.

Section B Answer one question.

The use of an approved scientific calculator is expected, where appropriate. A Data Booklet is provided.

The number of marks is given in brackets [] at the end of each question or part question.

This document consists of 20 printed pages and 4 blank pages.



Singapore Examinations and Assessment Board





Section A

Answer all the questions in this section in the spaces provided.

1 (a) Define the term *isotopes*.

Isotopes are atoms of the same element with the same number of protons but different

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number of neutrons. [1]

- (b) Compared to the isotope ${}_{2}^{4}$ He, a species has
 - . 8 times as many neutrons,
 - 9 times as many electrons,
 - . 13 more protons.

Deduce the symbol of this species and include its charge, if any, and its atomic and mass numbers.

³¹₁₅ P³⁻ Note: atomic number, mass number and charge must all be included in one single symbol [3]

Working:

Number of protons = 2 + 13 = 15Hence, the unknown species is <u>P</u>.

Number of electrons = 9(2) = 18 Hence, charge of unknown species = 3-

Number of nucleons = 8(4-2) + 15 = 31







(c) The relative atomic mass of an element depends on the percentage abundance of each isotope present.

isotope	relative isotopic mass	percentage abundance / %		
³² S	31.972	95.02		
³³ S	32.971	0.75		
³⁴ S	33.968	4.21		
³⁶ S	35.967	0.02		

Table 1.1

(i) A sample of sulfur contains four isotopes, as shown in Table 1.1.

3

Calculate the relative atomic mass of sulfur in this sample, giving your answer to **two** decimal places.

$$A_{r} = \sum \left(\text{relating isotopic mass} \times \frac{\text{percentage abundance}}{100} \right)$$
$$A_{r} = 31.972 \times \frac{95.02}{100} + 32.971 \times \frac{0.75}{100} + 33.968 \times \frac{4.21}{100} + 35.967 \times \frac{0.02}{100} = 32.06 \text{ (2 d.p.)}$$

Note: answer must be in 2 d.p. (as stated in the question) or no credit will be given

(ii) Suggest why the relative atomic mass in the Periodic Table for nickel is lower than that for cobalt.

A sample of cobalt contains primarily of the isotope ⁵⁹Co, while in a sample of nickel.

⁵⁸Ni is the isotope with the highest percentage abundance. [1]

(d) Nickel reacts with sulfur to form nickel(II) sulfide, NiS.

State the electronic configurations of the nickel ion, Ni^{2+} , and the sulfide ion, S^{2-} .

Ni ²⁺	1s ² 2s².2p⁶.3s².3p⁶.3d⁸	
S ²	1s ² 2s² 2p⁶ 3s² 3p⁶	

[2]

[Total: 9]







2 Airbags in cars help to protect the driver and passengers during a collision.

Early airbags contained a mixture of sodium azide, NaN₃, potassium nitrate, KNO₃, and silicon(IV) oxide, SiO₂.

A heavy collision completes an electrical circuit which ignites a pellet of sodium azide. The sodium azide decomposes and the nitrogen fills the airbag very quickly. This is shown in reaction 1.

The remaining chemicals then undergo a series of reactions, 2, 3 and 4.

reaction 1	$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$
reaction 2	$2\text{KNO}_3(\text{s}) + 10\text{Na}(\text{s}) \rightarrow 5\text{Na}_2\text{O}(\text{s}) + \text{K}_2\text{O}(\text{s}) + \text{N}_2(\text{g})$
reaction 3	$K_2O(s) + SiO_2(s) \rightarrow K_2SiO_3(s)$
reaction 4	$Na_2O(s) + SiO_2(s) \rightarrow Na_2SiO_3(s)$

(a) (i) Write half-equations to show the oxidation and reduction processes that occur in reaction 2.

oxidation $Na \rightarrow Na_{+} + e_{-}$

reduction $2NO_3^- + 10e^- \rightarrow N_2 + 6O^{2-}$ Note: species such as H₂O, H⁺ and O₂ should not appear in the half equations [2] as they are not present in reaction 2.

(ii) Identify the species which is being oxidised and the species which is being reduced. Explain your answers using oxidation numbers.

Na is oxidised as the oxidation number of Na increases from 0 in Na to +1 in Na₂O.

KNO₃ is **reduced** as the oxidation number of N decreases from +5 in KNO₃ to 0 in N₂.

[2]

(iii) Suggest the type of reaction occurring in reactions 3 and 4.

Acid-base reaction [1]

(b) The mass of sodium azide needed to produce just enough nitrogen gas from reaction 1 to inflate the airbag to a pressure of 1.00 atm is calculated to be 40.0 g.

Explain why using this mass of sodium azide would result in the pressure in the airbag being greater than 1.00 atm. No calculations are required.

[Assume that the temperature remains constant.]

Na produced from reaction 1 will react with the KNO₃ present via reaction 2 to form

additional N_2 gas, leading to the pressure in the airbag being greater than 1.00 atm. [1]







c) Reaction 1 produces enough nitrogen gas to inflate the airbag to a pressure sufficient to protect the people in the car.

5

Suggest why KNO_3 and SiO_2 are present in the mixture in the airbag.

KNO₃ is added to remove the Na produced in reaction 1 which is highly reactive and

potentially explosive if it comes into contact with water.

 SiO_2 is added to remove the Na₂O and K₂O produced in reaction 2 which will produce

corrosive NaOH and KOH if it comes into contact with water. [2]

(d) Sodium azide is ionically bonded.

Azide ions, N₃⁻, contain two double bonds.

Draw a 'dot-and-cross' diagram to show the bonding in an azide ion.



[1]

(e) Sodium azide is toxic and undergoes an acid-base reaction with **strong** acids to give a toxic product, hydrazoic acid.

Sodium azide can be made safe by reacting it with the **weak** acid nitrous acid, HNO₂. Nitrogen, nitrogen monoxide and an alkali are formed in this reaction.

(i) Suggest a formula for hydrazoic acid.

HN₃.....[1]

(ii) Write a balanced equation for the reaction of sodium azide with nitrous acid.

$2NaN_3 + 2HNO_2 \rightarrow 3N_2 + 2NO + 2NaOH$	۲ı	11
	[1

[Total: 11]





3 Butane undergoes complete combustion to form carbon dioxide and water.

Bond energies can be used to calculate a value for the enthalpy change of combustion of butane using the energy cycle shown in Fig. 3.1.

6





(a) Define the term standard enthalpy change of combustion.

The standard enthalpy change of combustion is the energy released when 1 mole of a substance is completely burnt in excess oxygen at 1 bar and at a specified temperature, usually 298 K.

(b) Use the energy cycle shown in Fig. 3.1, the bond energy values given in Table 3.1 and those in the *Data Booklet* to calculate a value for the enthalpy change of combustion of butane.

bond	bond energy/kJmol ⁻¹
C–H	410
C=O	805
O_H	460

Table 3.1

 $\Delta H_{c} = \frac{1}{2} \Delta H_{r} = \frac{\sum \text{BE(bonds broken)} - \sum \text{BE(bonds formed)}}{2}$ = $\frac{[2 \times 10 \times \text{BE}(\text{C} - \text{H}) + 2 \times 3 \times \text{BE}(\text{C} - \text{C}) + 13 \times \text{BE}(\text{O} = \text{O})] - [8 \times 2 \times \text{BE}(\text{C} = \text{O}) + 10 \times 2 \times \text{BE}(\text{O} - \text{H})]}{2}$ = $\frac{[20 \times 410 + 6 \times 350 + 13 \times 496] - [16 \times 805 + 20 \times 460]}{2}$ = $-2670 \text{ kJ mol}^{-1}$







(c) The accepted value for the standard enthalpy change of combustion of butane is different from the value calculated in (b).

7

One reason is that the bond energy values are only average values.

(i) State another reason why the accepted value for the enthalpy change of combustion of butane obtained under standard conditions is different from the value calculated in (b).

Bond energy values involve bond breaking in the gaseous state. However, in the reaction

involved in the enthalpy change of combustion of butane, water is in the liquid state.[1]

(ii) Suggest how the standard enthalpy change of combustion of butane would differ from that calculated in (b). Explain your answer.
Note: not higher or lower
It will be more exothermic than that calculated in (b) as energy is released when

water changes from the gaseous to liquid state. [1]

(d) State how the magnitude of the lattice energy of sodium chloride compares to that of magnesium oxide. Explain your answer.

Lattice energy of sodium chloride is **less exothermic** than that of magnesium oxide as $|\Delta H_{\text{tert}}| * \left| \frac{q_* * q_{\parallel}}{r_* + r_{\parallel}} \right|$ and Na⁺ and Ct⁻ have **lower charges** and **larger ionic radii** than Mg²⁺ and O²⁻.

Note: Comparisons of both the charges and ionic radii are required as both factors differ in the ions involved.

.....[3]

[Total: 12]





4 A new underground deposit of iron ore has been discovered which contains both Fe²⁺ and Fe³⁺ ions, as well as impurities. A 20.0g sample of this iron ore is analysed.

8

This sample is dissolved in an excess of sulfuric acid. The impurities in the ore are insoluble and do not react with sulfuric acid. The solution is filtered into a 250 cm^3 graduated flask. Deionised water is added so that the total volume of the solution is 250 cm^3 . This is solution X.

 $25.0 \,\text{cm}^3$ of solution X requires $15.60 \,\text{cm}^3$ of $0.060 \,\text{mol}\,\text{dm}^{-3}$ of potassium manganate(VII) solution for complete reaction.

 100 cm^3 of solution X is heated with an excess of zinc to reduce the Fe³⁺ ions to Fe²⁺ ions. The solution is filtered to remove excess zinc. The filtrate is solution Y.

A sample of solution Y is titrated against potassium manganate(VII) solution.

The equation for the reaction of Fe^{2+} ions and manganate(VII) ions is shown.

 MnO_4^- + 5Fe²⁺ + 8H⁺ \rightarrow Mn^{2+} + 5Fe³⁺ + 4H₂O

(a) (i) Calculate the number of moles of Fe^{2+} ions present in 250 cm³ of solution X.

Amount of KMnO₄ reacted =
$$\frac{15.60}{1000} \times 0.060 = 0.000936$$
 mol
Amount of Fe²⁺ in 250 cm³ of solution X = 5 × 0.000936 × $\frac{250}{25.0}$
= **0.0468 mol**

(ii) Calculate the percentage by mass of Fe²⁺ ions in the sample of ore.

Mass of
$$Fe^{2+} = 0.0468 \times 55.8 = 2.611 g$$

% by mass $= \frac{2.611}{20.0} \times 100\% = 13.1\%$

[2]

[1]







(b) Write an ionic equation for the reaction between Fe^{3+} ions and zinc.

$$2Fe^{3+} + Zn \rightarrow 2Fe^{2+} + Zn^{2+}$$
[1]

9

(c) The number of moles of Fe^{2+} in 100 cm^3 of solution Y is calculated to be 0.0560 mol.

Calculate the number of moles of Fe^{2+} ions in 250 cm³ of solution Y and, hence, determine the number of moles of Fe^{3+} ions in 250 cm³ of solution X.

Amount of Fe²⁺ in 250 cm³ of Y = $\frac{250}{100} \times 0.0560 = 0.140$ mol Amount of Fe³⁺ in 250 cm³ of Y = 0.140 - 0.0468 = **0.0932 mol**

[1]

(d) The ore is an oxide containing both Fe^{2+} and Fe^{3+} ions.

Suggest the Fe: O mole ratio for this oxide. Explain your suggestion, using your knowledge of oxidation numbers and your answers to (a)(i) and (c).

Amount of Fe^{2+} : Amount of $Fe^{3+} = 0.0468: 0.0932 = 1:2$. For every Fe^{2+} ion, there will be two

Fe³⁺ ions, resulting in a total charge of +8. Hence, **four O²⁻ ions** are required to balance

the charge of **three iron ions**, and the Fe:O mole ratio is **3:4**. [2]

(e) In this experiment there are potential sources of error, including

- · error 1: incomplete reaction of the sample of iron ore with the sulfuric acid,
- error 2: incomplete reduction of the Fe³⁺ ions to Fe²⁺ ions.

Explain the effect, if any, that each error will have on the amount, in moles, of Fe^{2+} calculated in **(a)(i)** and of Fe^{3+} calculated in **(c)**.

Error 1 will result in lower amounts of both Fe²⁺ and Fe³⁺ in solution X and hence less Fe²⁺

in solution Y. This leads to lower titre values in both titrations and hence lower calculated

amounts of both Fe2+ and Fe3+. Error 2 will have no effect on the amount of Fe2+

calculated in (a)(i). However, it will result in less Fe²⁺ in solution Y and hence lower titre

value in the second titration, leading to a lower amount of Fe³⁺ calculated in (c)



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The polymer poly(ethylene terephthalate) is also known as PET.

It is made from the two monomers shown.



PET is a thermoplastic polymer which can be used for making bottles.

(a) (i) Name the two monomers used to make PET.

benzene-1,4-dicarboxylic acid and ethane-1,2-diol

-[2]
- (ii) Draw one repeat unit of PET.



	(iii)	State the type of polymerisation that produces PET and name the bond formed during this polymerisation.
		Condensation polymerisation, ester linkage [1]
(b)	Exp	lain why PET should not be used for storing alkaline cleaning materials.
	Th	e ester linkage will undergo alkaline hydrolysis , causing degradation of PET.
		[1]
(c)	(i)	State one environmental advantage of recycling PET.
		Recycling PET can help to reduce fossil fuel consumption. The fuel needed for
		recycling is less compared to that needed to make new PET. [1]
	(ii)	Suggest why a medicine bottle made of PET should not be reused for storing drinks such as water.
		Chemicals in the medicine may have hydrolysed PET, resulting in chemical
		leeching from the PET bottle. [1]

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(d) A polymer is to be used to make a part in a machine.

The polymer has to be strong and a little flexible.

Samples of various polymers are made into sheets. These sheets are supported at opposite ends and masses are added to the centre of the sheets.

As the masses are added, the amount the polymer bends, in degrees, is measured until the polymer breaks.

The results are shown in Fig. 5.1.





(i) Identify three variables which must be controlled during this test.

variable 1. Thickness of sheets
variable 2. Breadth and length of sheets
variable 3 Temperature

[2]

(ii) Suggest which polymer should be chosen in preference to the other four for use in the machine.

Explain your choice.

Polymer D. D is strong as it is able to withstand the largest mass before breaking compared to the rest of the polymers. It is also a little flexible as the amount of bend increases slightly with increasing mass added.

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(iii) Polymers C and D are made from the same hydrocarbon monomer.

Suggest and explain the difference in the structures of polymers C and D.

Explain how this causes the difference in their properties shown in Fig. 5.1.

Polymer C is likely to be a LDPE with shorter and more branched chains while polymer D is likely to be a HDPE with longer and more linear chains. The branched chains of polymer C are packed less closely together as compared to the linear chains in polymer D. As a result, the instantaneous dipole-induced dipole between the molecules in polymer C are not extensive as in polymer D, leading to lower tensile strength and greater flexibility. [3]

(e) Poly(vinyl alcohol), PVA, is a polymer which is soluble in water.

Explain how PVA dissolves in water.

Include a diagram in your answer.



The **-OH group** present in PVA is able to **form favourable hydrogen bonds with water molecules**. Hence, PVA is soluble in water.

.....[3]







(f) The gecko is able to climb vertical walls and is possibly the largest animal that can hang from the ceiling with its feet above its head.

It is only recently that scientists have been able to understand how the gecko is able to do this and as a consequence design materials which can mimic this behaviour.

One such material that scientists have invented is a tape which can stick to many surfaces but which is easily removed.

Suggest and explain the feature of this tape which enables it to stick to a surface in a similar way to that of a gecko hanging on the ceiling.

The tape has millions of synthetic fibers which form instantaneous dipole-induced

dipole interactions with surfaces. Individually the interactions are weak, but cumulatively

the large surface area to volume ratio due to the micro- and nanoscale structures in the

fibres results in strong adhesive forces.

......[2]

[Total: 19]





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15



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Section B

Answer one question from this section in the spaces provided.

- 6 (a) Propanoic acid is a weak acid.
 - (i) Explain the meaning of the term *weak acid*.

A weak acid **dissociates partially** in water to **form H₃O⁺(aq)**.

.....[2]

(ii) Write an equation for the equilibrium between propanoic acid and water.

Label the conjugate acid and the conjugate base in your equation.

 $\begin{array}{rrrr} CH_{3}CH_{2}COOH(aq) + H_{2}O(I) \rightleftharpoons CH_{3}CH_{2}COO^{-}(aq) + H_{3}O^{+}(aq) \\ acid & base & conjugate base & conjugate acid \\ \end{array}$

(iii) Define pH.

pH = -lg[H⁺] [1]

(iv) Calculate the pH of 0.015 mol dm⁻³ sulfuric acid. Assume that all the hydrogen ions in sulfuric acid are fully dissociated.

 $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$ pH = -lg (2 × 0.015) = **1.52**

[2]

(b) When sodium iodide reacts with concentrated sulfuric acid, iodine is formed as one of the products.

When sodium chloride reacts with concentrated sulfuric acid, chlorine is **not** formed as a product.

Explain why, when concentrated sulfuric acid is reacted with these halide salts, iodine is formed but chlorine is not.

Chloride is less easily oxidised as it has a smaller ionic radius than iodide, and hence a

- lower tendency to lose electrons. [1]
- (c) (i) Name the structure of solid iodine and of solid sodium iodide.

Solid iodine: simple molecular structure		
Solid sodium iodide: giant ionic lattice structure	[1	harmen





(ii) Explain why solid iodine turns into a vapour when it is heated gently, but solid sodium iodide does not.

When solid iodine is heated, sufficient energy is supplied to overcome the weak instantaneous dipole-induced dipole interactions between the iodine molecules. However, the energy supplied is not sufficient to overcome the strong electrostatic forces of attraction between the oppositely charged Na⁺ and I⁻ ions in sodium iodiple.

(d) The reaction between the reagents F, G and H is studied at constant temperature.

The rate equation is found to be

rate =
$$k [F]^{0} [G]^{1} [H]^{2}$$

(i) Complete Table 6.1 for this reaction.

experiment	initial concentration of F /moldm ⁻³	initial concentration of G /moldm ⁻³	initial concentration of H /moldm ⁻³	initial rate /moldm ⁻³ h ⁻¹
1	0.1	0.2	0.2	1.92 × 10 ⁻⁶
2	0.2	0.4	0.4	1.54 × 10⁻⁵
3	0.4	0.4	0.1	9.60 × 10 ⁻⁷
4	0.3	0.6	0.2	5.71 × 10 ⁻⁶

Table 6.1

(ii) Use the data from experiment 1 to calculate a value for the rate constant k.

rate = 1.92×10^{-6} = k × 0.2 × (0.2)² k = **2.40 × 10⁻⁴ mol⁻² dm⁶ h⁻¹**

value of *k*. **2.40 × 10**⁻⁴ [1]

(iii) Deduce the units of k.

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[3]





(iv) Complete Fig. 6.1 to show how the rate constant varies with the concentration of H, at constant temperature.



Fig. 6.1

- [1]
- (v) State and explain the effect on the rate of this reaction when only the [G] is increased at constant temperature.

Rate of reaction will increase proportionally with [G] as the reaction is first order

with respect to G.

-[1]
- (e) There are four isomeric alcohols with the formula $C_4H_{10}O$.

Name and draw the structure of the isomer which does **not** react with acidified potassium dichromate(VI).

H₃C-Ċ -CH3 OH

2-methylpropan-2-ol

[2]

[Total: 20]





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(a) Pure samples of ethanol and ethanoic acid are mixed, and equilibrium is established, as shown.

$$C_2H_5OH(I) + CH_3CO_2H(I) \rightleftharpoons CH_3CO_2C_2H_5(I) + H_2O(I)$$

(i) Write an equilibrium expression, K_c , for this reaction.



[1]

[1]

(ii) The reaction mixture is allowed to reach equilibrium at constant temperature.

In this equilibrium mixture the concentrations are:

- ethanol, 0.56 mol dm⁻³
- ethanoic acid, 0.94 mol dm⁻³

The $K_{\rm c}$ value is 3.98.

Calculate the equilibrium concentration of ethyl ethanoate.

$$\mathcal{K}_{c} = \frac{[CH_{3}CO_{2}C_{2}H_{5}][H_{2}O]}{[C_{2}H_{5}OH][CH_{3}CO_{2}H]}$$

$$3.98 = \frac{x^{2}}{0.56 \times 0.94}$$

$$[CH_{3}CO_{2}C_{2}H_{5}] = x = \sqrt{3.98 \times 0.56 \times 0.94}$$

$$= 1.45 \text{ mol dm}^{-3}$$

(iii) State and explain the immediate effect on the equilibrium of adding a few drops of aqueous sodium hydroxide to the mixture.

The sodium hydroxide added will react with the ethanoic acid, decreasing the concentration of ethanoic acid. Hence, the position of equilibrium will shift to left to increase the concentration of ethanoic acid,

-[2]
- (b) Calculate the pH of a $0.400 \text{ mol dm}^{-3}$ solution of sodium hydroxide.

 $\begin{bmatrix} OH^{-} \end{bmatrix} = 0.400 \text{ mol } dm^{-3}$ pOH = -lg(0.400) pH = 14 - (-lg(0.400)) =**13.6**





(c) Sodium sulfide is a white solid with a melting point of 1176 °C.

(i) Explain why sodium sulfide has a high melting point, in terms of its structure and bonding.
Sodium sulfide has a giant ionic lattice structure with strong electrostatic forces of attraction between oppositely charged ions. A large amount of energy is required

to overcome the strong bonds, hence sodium sulfide has a high melting point. [2]

(ii) Sodium sulfide dissolves in water.

Use your knowledge of the Periodic Table to predict a value for the pH of the solution formed. Explain how you arrived at your answer.

 S^{2-} is a **basic anion** like O^{2-} . However, as S^{2-} is **larger** than O^{2-} , its **attraction for H⁺ from H₂O**

is weaker. Hence, the pH of a solution of Na₂S is about 10, which is lower than that of Na₂O. [1]

(d) (i) Define the term activation energy.

Activation energy is the **minimum amount of energy** that the reactant particles must have to collide effectively to form products. [1]

(ii) Draw and label a Boltzmann distribution curve for the molecular energies of a sample of a gaseous reaction mixture.

On your diagram, draw a line to represent the activation energy. Label this line E_a .



The graph should not become a horizontal straight line at high energy levels

[3]

Graph needs to start from origin





- On the Boltzmann distribution curve in d(ii) show the change that would happen when a (111) catalyst is added to the reaction mixture. Temperature and pressure are kept constant. Label the change J. [1]
- (e) Ethene reacts with hydrogen in the presence of a nickel catalyst to form ethane.
 - State what is meant by the term *heterogeneous* when it is applied to a nickel catalyst in (i) the reaction of ethene and hydrogen.

A heterogeneous catalyst is a catalyst that is in a different physical phase from the

reactants. In this case, nickel is a solid while ethene and hydrogen are gases. Note: need to discuss definition using context given in guestion (Ni catalyst, H₂ and C₂H₄

Outline, in three stages, the mode of action as nickel catalyses the reaction between (ii) ethene and hydrogen to form ethane.

Stage 1: Ethene and hydrogen molecules physically adsorb onto the active sites of

the solid nickel surface, increasing the local concentration of reactants. The weak

intermolecular forces of attraction formed between the reactant molecules and the

active sites weaken the covalent bonds in the reactant molecules.

Stage 2: Adjacent ethene and hydrogen molecules react to form products.

Stage 3: After the reaction, the adsorbed ethane molecules desorbs from the catalysis

surface and **diffuse away** from the nickel surface. There are four isomeric alcohols with the formula $C_4H_{10}O$. They can all form alkenes when (f) undergoing elimination reactions.

Name and draw the structure of the isomer which forms an alkene that exhibits cis-trans isomerism.



[2]

[Total: 20]



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