O Level Pure Chemistry Structured

Energy from Chemicals Test 2.0

Q1

The equation below shows the reaction for the conversion of ammonia to nitrogen(II) oxide.

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g) \qquad \Delta H = -950 \text{ kJ/mol}$$

Is the reaction exothermic or endothermic? Explain your answer, in terms of the energy changes that take place during bond breaking and bond making, why the reaction is exothermic or endothermic.

[2]

Q2

Heat packs are commonly used by walkers and climbers as hand or body warmers. One of the ingredients found in heat packs is powdered iron.

All the ingredients are contained in a plastic bag. When the bag is opened, air enters the pack and it slowly heats up and remains at a temperature of about 40 °C for several hours. The equation represents the chemical reaction taking place in the heat pack.

$$4Fe + 3O_2 + 5H_2O \rightarrow 2Fe_2O_3.5H_2O$$

(a) Identify the substance that is oxidised during the reaction. Explain your answer in terms of electrons transfer.

.....

.....[2]

(b) Sketch a labelled energy profile diagram for the reaction taking place in the heat pack, indicating clearly the reactants, products, activation energy (E_a), and enthalpy change (ΔH).

[2]

(c) In certain brands of the heat pack, a carbon catalyst is added to it.

Explain, in terms of the collision theory, why is the carbon catalyst added to the heat pack.

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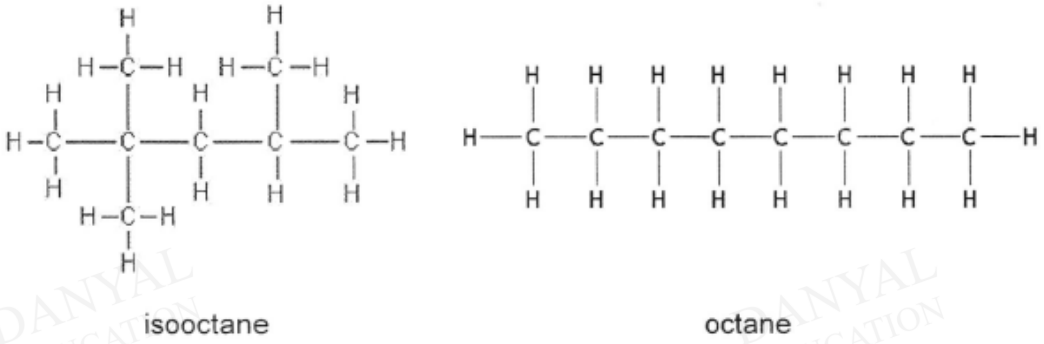
.....[3]

[Total: 7]

Q3

(a) 2,2,4-trimethylpentane, also known as isooctane, is an isomer of octane C_8H_{18}.

The structures of isooctane and octane are shown in Fig. 7.1.



isooctane octane

Fig. 7.1

The enthalpy changes of combustion and boiling points for isooctane and octane are given in the Table 7.1.

Table 7.1

hydrocarbon	enthalpy change of combustion/ kJ mol^{-1}	boiling point/ °C
isooctane	- 5460	99.3
octane	- 5460	126.1

(i) Write a balanced equation for the complete combustion of isooctane.

……[1]

(ii) Suggest why the enthalpy change of combustion for isooctane and octane are the same.

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……[2]

Q4

The Hydra is a 22-person hydrogen fuelled ship that gets its electricity from a hydrogen fuel cell. It converts chemical energy from hydrogen fuel into electricity through a chemical reaction with oxygen, using aqueous sodium hydroxide as the electrolyte.
Fig. 4.1 shows the hydrogen fuel cell.

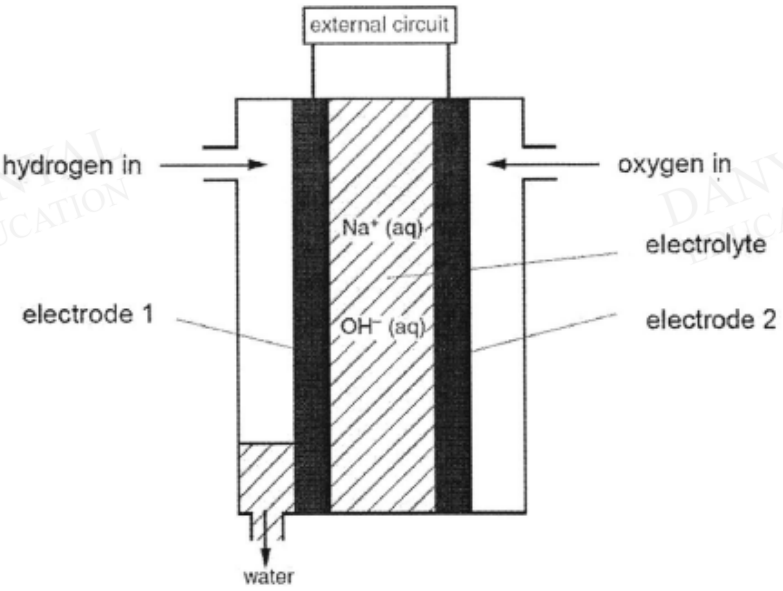

Fig. 4.1

The electrode reactions are:

O_2 (g) + $2H_2O$ (l) + 4e → $4OH^-$
H_2 (g) + $2OH^-$ (aq) → 2e + 2 H_2O (l)

(a) Identify which electrode in Fig. 4.1 is an anode, and which is a cathode.

.....[1]

(b) Describe how electricity is generated in the fuel cell.

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.....[2]

(c) Give two reasons why aqueous sodium hydroxide is preferred over molten sodium hydroxide as an electrolyte for the fuel cell.

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..... [2]

(d) The overall equation of the hydrogen fuel cell is as such:

$2H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (l)$

(i) Explain, in terms of oxidation states, if the overall reaction is a redox reaction.

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..... [2]

(ii) The generation of electrical energy from fuel cell is similar to the exothermic reaction that occurs when hydrogen gas reacts with oxygen gas.
Using ideas about bond breaking and bond making, explain why this reaction generates electrical energy.

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..... [2]

(iii) Hence sketch an energy profile diagram for the generation of electrical energy from fuel cells.

[2]

(e) Alternatively, methanol can be used as a fuel to form a methanol fuel cell. Other than in terms of energy produced, suggest a possible advantage of using the methanol fuel cell over the hydrogen fuel cell.

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..... [1]

Q5

A4 An investigation was carried out into the energy changes that occur when different metals were added to copper(II) sulfate solution. 3 cm^3 of copper(II) sulfate solution was added to each of six test tubes and the temperature of each solution was taken. An equal mass of metal was added to each test tube, the contents stirred and the temperature of the mixtures noted after one minute.

metal added	initial temperature of copper(II) sulfate solution / °C	temperature of mixture after 1 min / °C	temperature rise / °C
magnesium ribbon	20.0	29.0	
magnesium powder	20.5	56.0	
zinc granules	19.0	25.0	
zinc powder	21.0	41.0	
iron granules	18.5	20.0	
iron powder	19.5	34.5	

(a) Complete the table by writing down the temperature rise for each metal added. [1]

(d) (i) Draw an energy profile diagram for any of the reactions that occurred between each metal and copper(II) sulfate solution.

Your diagram should include

- the formulae of the reactants and products.
- a label for the reaction enthalpy change, ΔH and
- a label for the activation energy, E_a.

[3]

(ii) Each of the reaction was repeated in the presence of a catalyst.
What effect does the catalyst have on the activation energy and the enthalpy change?

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.....[1]

Answers

Energy from Chemicals Test 2.0

Q1

Exothermic	1
More heat energy is given out when bonds between N–O and H–O are formed than is taken in for breaking the N–H bonds and O=O bonds.	1

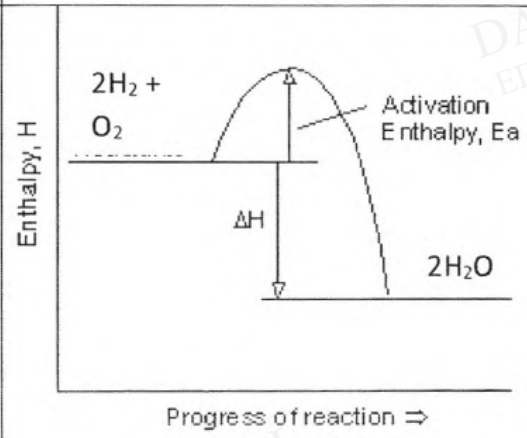
Q2

(a)	Iron/Fe; Each Fe atom loses 3 electrons to form Fe^{3+} ions/Fe_2O_3; A: loses electrons to form Fe^{3+}	[1] [1]
(b)	R: -ΔH	[1] for exo energy profile diagram [1] for all correct labels unlabelled /incorrect axes -1m
(c)	Catalyst allows the pack to heat up faster; More colliding particles possess energy equal to or greater than activation energy; Frequency of effective collisions increases, speed of reaction increases; R: more effective collisions, number of effective collisions increases	[1] [1] [1]

Q3

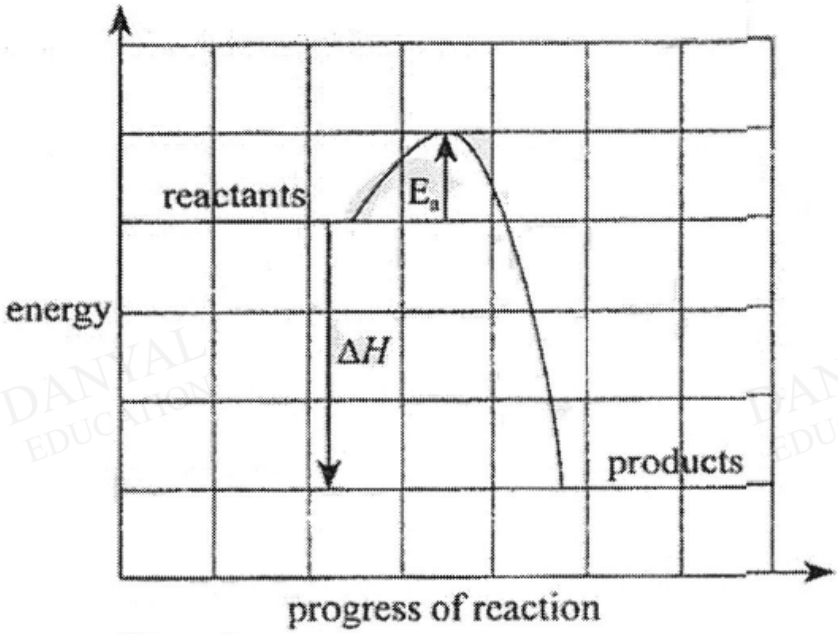
(a)(i)	$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$;	[1]
(a)(ii)	The number of C-H and C-C bonds broken, as well as the number of C=O and O-H bonds formed are the same for both hydrocarbons; Same amount of energy taken in/absorbed and given out/released; R: same number of bonds/same bonds are broken and formed	[1] [1]

Q4

A4(a)	Anode: electrode 1 / on the left Cathode: electrode 2 / on the right	½ ½
(b)	Hydrogen gas is **oxidised** and releases electrons and water. These electrons flow from the anode to the cathode. Oxygen is then **reduced** to form hydroxide ions. The **movement of electron flow** from hydrogen to oxygen in the cell generates electricity.	½ ½ 1
(c)	**High temperature** is required to maintain sodium hydroxide in the **molten state**. **Sodium metal deposited at the positive electrode would react with the oxygen** supplied, reducing the efficiency of the fuel cell.	1 1
(d)(i)	The overall reaction for the hydrogen fuel cell is a redox reaction. The hydrogen is oxidised as the oxidation state of hydrogen increases from **0 in H_2 to +1 in H_2O** while oxygen is reduced as the oxidation state of oxygen decreases from **0 in O_2 to -2 in H_2O.**	1 1
(ii)	The amount of electrical energy **absorbed** to **break** 2 moles of H-H and 1 mole of O=O bonds in H_2 and O_2 is **lesser** than energy **released** when the 4 moles of H-O bonds in H_2O are **formed**. Thus, it is an exothermic reaction and there is a **net amount of electrical energy released.**	2
(iii)		2
(e)	Methanol is a liquid and is not required to be stored under highly pressurized vessels unlike hydrogen. Thus it is safer to transport as a fuel.	1

Q5

d i



- 1m for correct Ea
- 1m for correct ΔH
- 1m for correct shape of graph and labelling of formulae of reactants and products.
  Note: Formulae of reactants and products depend on the reaction of metal used.

ii Activation energy decreases and enthalpy change is unchanged.
[both answers must be correct to score 1 m]