O Level Pure Chemistry Structured

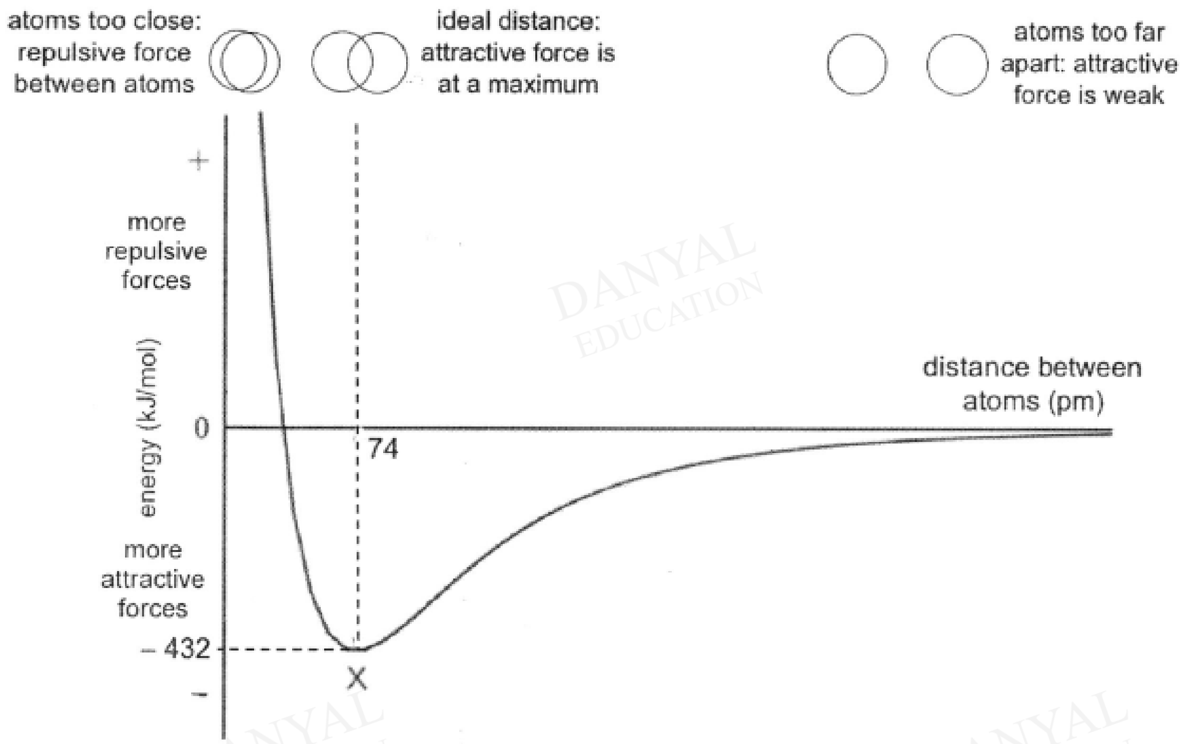
Energy from Chemicals Test 1.0

Q1

The formation of a covalent bond involves the sharing of electrons between atoms, forming a stable balance between attractive and repulsive forces between the two atoms being bonded.

In a hydrogen molecule, H_2, the hydrogen atoms share two electrons via covalent bonding. The bond energy is the amount of energy needed to break one mole of a covalent bond. The bond energy of a H – H bond is 432 kJ/mol.

The graph below shows how the bond energy between the two hydrogen atoms varies with the distance between their nuclei.



A positive energy value means that repulsive forces between the atoms' nuclei are dominant.
A negative energy value means that attractive forces between the atoms' nuclei are dominant.

The bond length is the average distance between the nuclei of two bonded atoms in a molecule where the attractive force is greatest. For a hydrogen molecule, this distance is 74 picometres (pm).

The table below shows how the H–H bond compares with the number of bonds, bond lengths and bond energies of some elements in Period 2.

type of bond	number of bonds	average bond energy (kJ/mol)	bond length (picometres)
H – H	1	432	74
O – O	1	142	148
O = O	2	494	121
N – N	1	167	145
N = N	2	418	
N ≡ N	3	942	110
F – F	1	155	142

(a) **(i)** Use the graph to describe how the H–H bond energy changes with the distance between the two hydrogen atoms.

....

....

....

....

....

....[3]

(ii) With consideration of how the sub-atomic particles are arranged in an atom, suggest why the bond energy is lowest at 74 picometres.

....

....

....

....[2]

(b) **(i)** Draw dot-and-cross diagrams to show the covalent bonding in nitrogen and fluorine, showing all the electrons.

nitrogen molecule:

fluorine molecule:

[2]

(ii) "The greater the number of bonds, the shorter the bond length."

Do you agree with this statement? Use the information in the table to explain your reasoning.

....

....

....

....

....

....[2]

(iii) Use the information in the table to predict the length of the N=N bond.

....[1]

(c) When nitrogen reacts with oxygen to produce nitrogen monoxide, the reaction is endothermic.

The bond energy of the N=O bond is 607 kJ/mol, and the enthalpy change of reaction is +222 kJ/mol.

Explain, in terms of bonds broken and formed, why this reaction is endothermic.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………[2]

[total = 12 marks]

Q2

The manufacture of sulfuric acid is described below.

step 1: Sulfur is burnt in excess air to form sulfur dioxide.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

step 2: Sulfur dioxide reacts with more oxygen to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196 \text{ kJ/mol}$$

step 3: Sulfur trioxide is dissolved in concentrated sulfuric acid to form oleum, $H_2S_2O_7$.

$$H_2SO_4(l) + SO_3(g) \rightarrow H_2S_2O_7(l)$$

step 4: Oleum can then react safely with water to produce concentrated sulfuric acid.

$$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$$

(a) Is step 3 a redox reaction? Use ideas about oxidation states to explain your answer.

....

....

....

.... [2]

(b) Explain, in terms of collisions between reacting particles, how a higher pressure affects the rate of reaction in step 1.

....

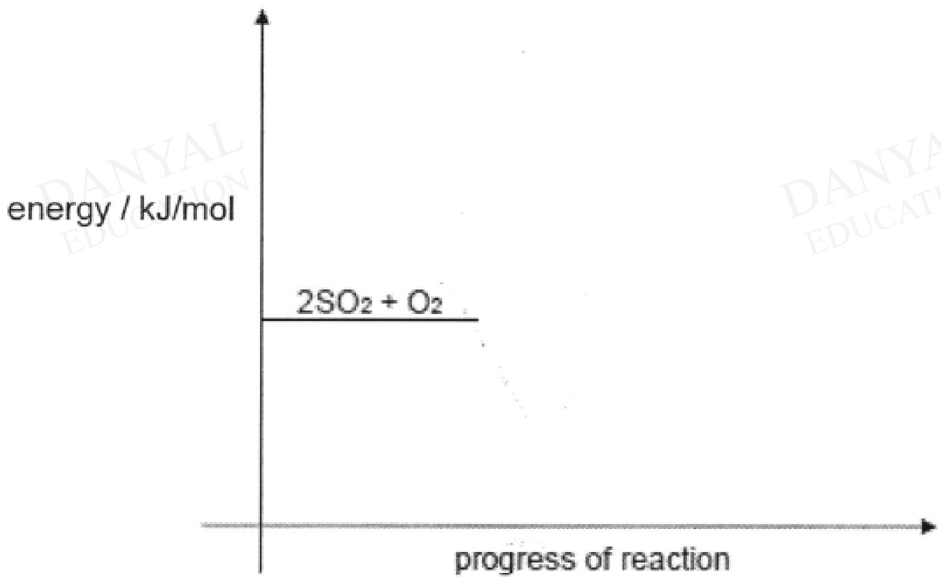
....

....

.... [2]

(c) **(i)** Complete the energy profile diagram below for the reaction of sulfur dioxide and oxygen to produce sulfur trioxide. The activation energy for this reaction is 2200 kJ/mol.

Label clearly the **reaction enthalpy change** and the **activation energy.**



[3]

(ii) State the values of the enthalpy change, ΔH, and the activation energy, Ea, of the reverse reaction.

ΔH = ……………………………kJ/mol

Ea = ……………………………kJ/mol [2]

[Total: 9]

Q3

A4 One of the main stages in the manufacture of sulfuric acid is the reaction between sulfur dioxide and oxygen to produce sulfur trioxide, SO_3. The reaction is reversible.

(a) Write a balanced chemical equation for this reaction.

....
[2]

(c) The enthalpy change of reaction (ΔH) for the conversion of sulfur dioxide to sulfur trioxide is '– 196 kJ / mol'.

(i) Use ideas about breaking and forming bonds to explain why the value is negative.

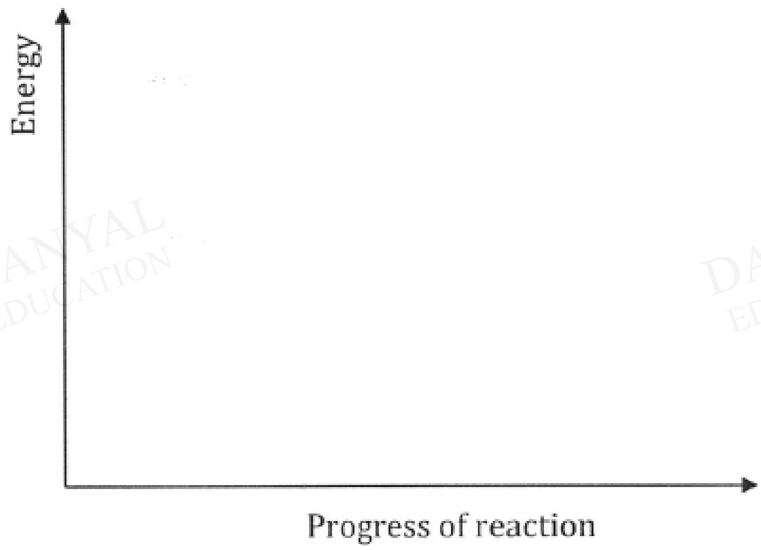
....

....

....

....
[3]

(ii) Draw the energy profile diagram for this reaction, clearly indicating the **formulae** of the reactants and products, and the *enthalpy change* and *activation energy* in your diagram.



[3]

Q4

Methanol, CH_3OH, is manufactured from carbon dioxide and hydrogen.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta H = -49\text{ kJ}$$

The reaction is carried out in the presence of a catalyst containing copper. The conditions used are 70 atmospheres pressure and a temperature of 250 °C.

(a) Explain, using collision theory, what happens to the speed of the reaction if the temperature of the reaction mixture is increased to 400 °C,

....

....

....

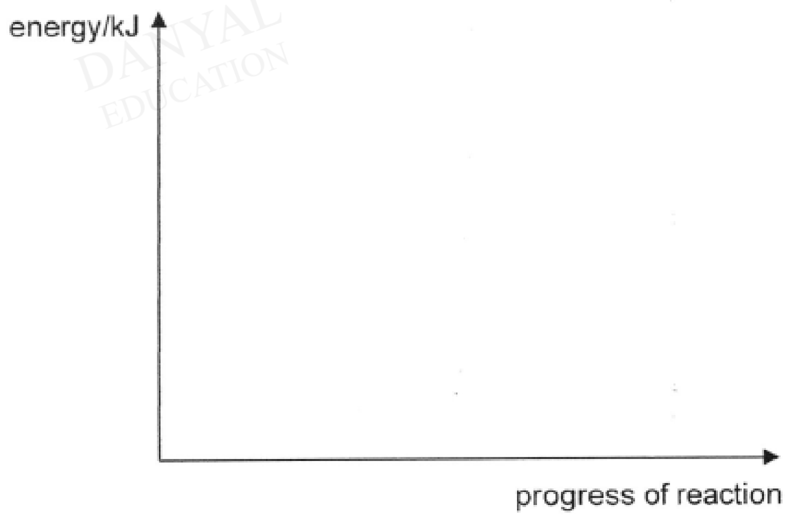
.... [2]

(b) In the reaction when 3.0 moles of hydrogen gas react, 49 kJ of heat energy is released. Calculate how much heat energy is released when 500 kg of hydrogen gas react.

[2]

(c) Complete the energy profile diagram using the given axes to show the production of methanol. The diagram should show:

- the activation energy, E_a;
- the energy change for the reaction, ΔH;
- the reaction pathway for the reaction

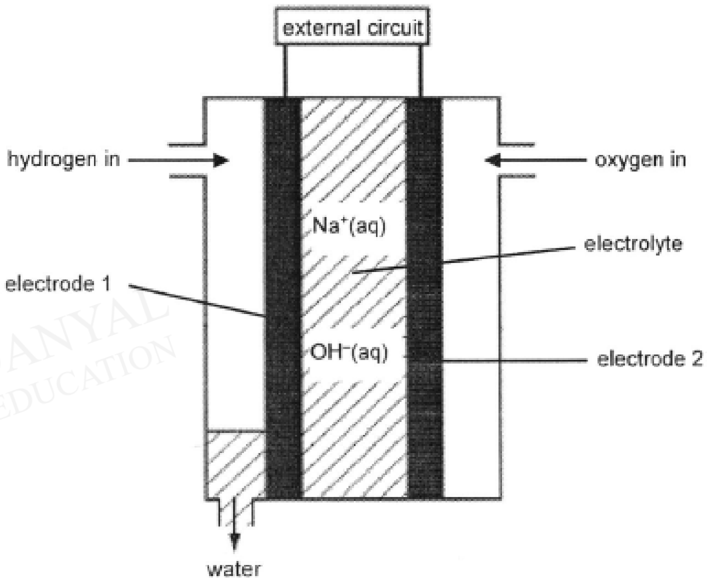


[2]

[Total: 6]

Q5

The NASA space shuttle uses fuel cells to generate electricity. The diagram shows a hydrogen-oxygen fuel cell.



(a) Identify which electrode above is an anode, and which is a cathode.

.... [1]

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

....

....

....

.... [3]

(c) Give one source for hydrogen for use in a fuel cell.

....

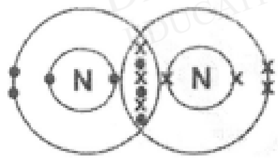
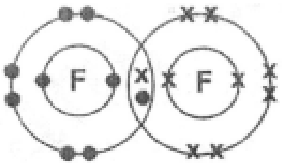
.... [1]

[Total: 5 marks]

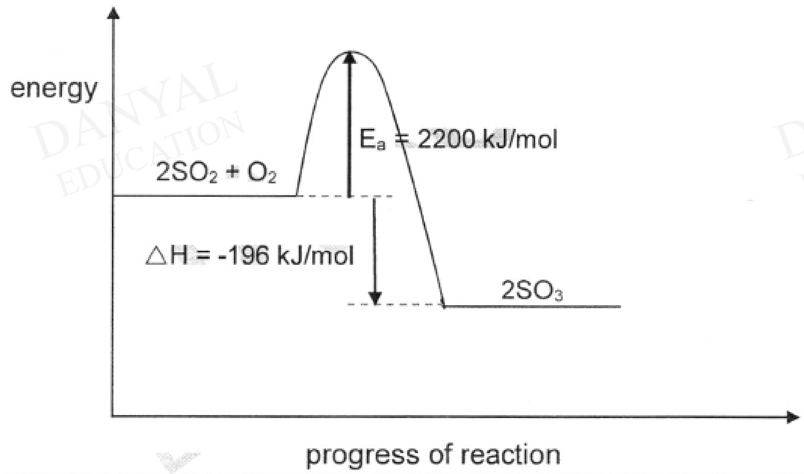
Answers

Energy from Chemicals Test 1.0

Q1

(a)(i)	When the distance between the two hydrogen atoms increases, the bond energy <u>decreases</u> [1] to a minimum energy of <u>-432 kJ/mol</u> at <u>74pm</u> [1] When the distance is greater than 74pm, the H-H bond energy <u>increases</u> to almost 0 kJ/mol. [1] *(Answers that only mention positive/negative energy will be awarded max. 2 marks)*	**[3]**
(a)(ii)	At 74pm, there is the <u>greatest attraction</u> [1] of the negatively-charged <u>electrons</u> in one atom to the positively-charged <u>protons</u> in the other atom. [1] *(If no mention of negative/positive charges of electrons/protons, or the "greatest" attraction, max. 1 mark)*	**[2]**
(b)(i)	 [1]  [1]	**[2]**
(b)(ii)	Do not agree. H-H is a single bond / 1 bond, but the bond length is the lowest at 74pm compared to NαN, where there is a triple bond but the bond length is longer at 110pm. [1] OR Agree. O=O has a double bond / 2 bonds and a longer bond length of 121pm compared to NαN at 110pm. [1] (any combination is fine, best is to compare between same type of atoms)	**[2]**
	(last mark is for data)	
(b)(iii)	Any number between 115 – 135pm (actual value is 125pm)	**[1]**
(c)	There is more energy taken in to break the NαN and O=O bonds [1] than energy given out to form the N-O/N=O bonds. [1]	**[2]**

Q2

A5a	No. The oxidation states of S, O and H remains the same at +6, -2 and +1 respectively in both reactants and products.	Minus 1 mark for each mistake in oxidation states.
b	The rate of reaction is faster at higher pressure. The gas molecules are closer together. There are more molecules per unit volume of the gas and they collide more frequently.	1 1
c(i)		correct Ea – 1m correct △H – 1m correct exothermic graph – 1m
(ii)	ΔH = +196 kJ/mol Ea = 2396 kJ/mol	1 1

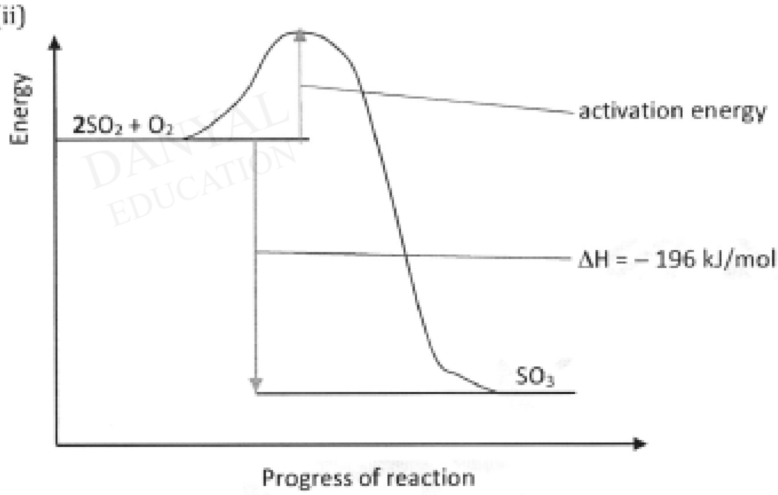
Q3

(a) $2SO_2 + O_2 \rightleftharpoons 2SO_3$ [2]

Award 1m for all correct symbols and balanced equation.
Award 1m for the '⇌' reversible arrow.

(c) (i) Energy <u>absorbed</u> in breaking bonds is <u>less than</u> [1[the energy <u>released</u> [1] in forming bonds. Hence the reaction is <u>exothermic</u>. [1] [3]

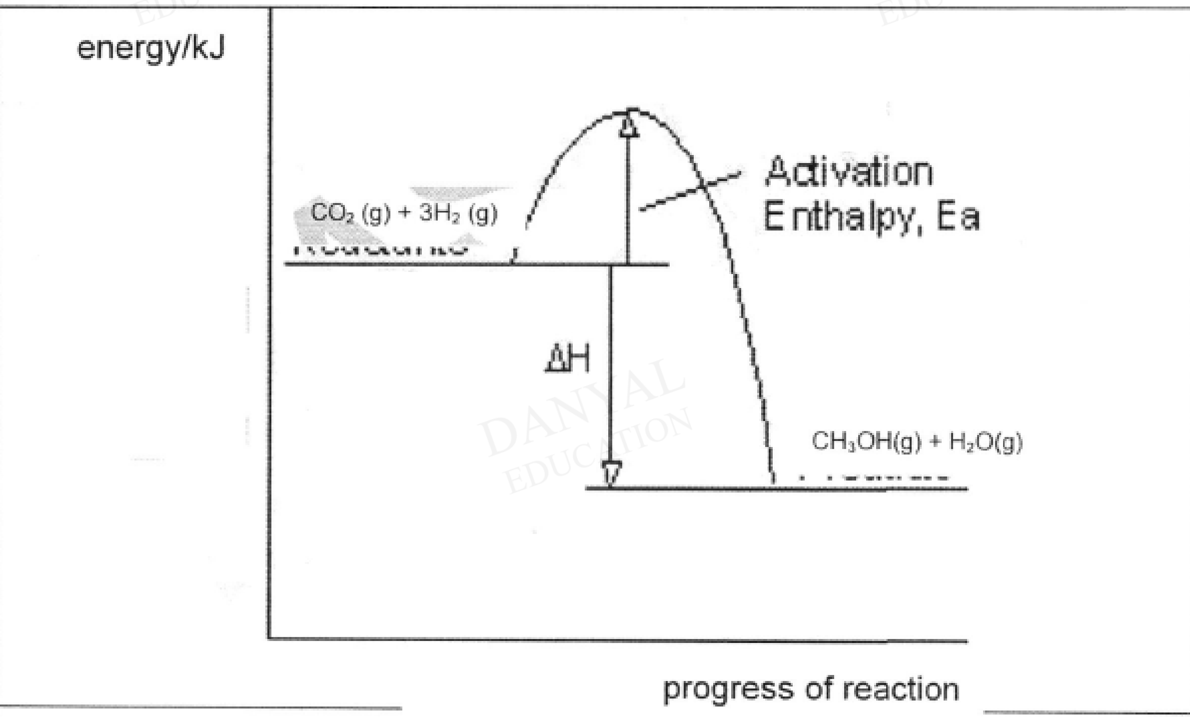
(ii)



[3]

Award 1m for correct energy profile diagram.
Allow for ECF from (c)(i).
In event 'endothermic' reaction is stated in (c)(i), the profile for (ii) must match.
Award 1m for correctly labelling enthalpy change or ΔH (including ↓ arrow) and activation energy (including ↑ arrow).
Award 1m for correctly labelling reactants and products.

Q4

(a)	The speed of reaction increases **More** reacting particles gain energy, move faster and will **attain energy equal or more than the activation energy** **Higher frequency of effective collisions** of the reacting particles	[1] [1]
(b)	Number of moles of hydrogen gas = 500 x 10^3 / 2(1) = **250 x 10^3** Energy released = (250 x 10^3 / 3) x 49 = **4.08 x 10^6 kJ**	[1] [1]
(c)		[2]

Q5

(a)	Anode: electrode 1 Cathode: electrode 2	1
(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.	1 1 1
(c)	Cracking of crude oil / petroleum / large alkane, alkene, hydrocarbon OR Electrolysis of water	1