O Level Pure Chemistry Structured

Energy from Chemicals Test 3.0

Q1

Hydrazine is a compound often used in rocket fuels as it can be stored conveniently in liquid form, reacts exothermically with oxygen, and produces only gaseous products in the process.

The reaction of hydrazine with oxygen (Reaction **I**) can be expressed as follows:

$$N_2H_4(g) + O_2(g) \rightarrow N_2(g) + 2H_2O(g) \qquad \Delta H = -622 kJ/mol$$

It has been suggested that the reaction between hydrazine and fluorine (Reaction **II**) is more exothermic than that between hydrazine and oxygen.

Reaction II

$$N_2H_4(g) + 2F_2(g) \rightarrow N_2(g) + 4HF(g)$$

Bond energy is the energy released when a bond is formed between two atoms or the energy required to break a bond between two atoms.

The following table shows the bond energies of selected covalent bonds, measured in kilojoules per mole.

bond	bond energy in kJ/mol
F – F	158
N – N	160
N – H	390
H – F	565
N = N	418
N ≡ N	945

(a) Draw a dot-and-cross diagram to show the covalent bonding in hydrazine.
Show outer shell electrons only.

[2]

(b) Using the bond energies given above,

(i) calculate the amount of energy (kJ) required to break all the bonds in the reactants in Reaction II;

[1]

(ii) calculate the amount of energy (kJ) released when all the bonds are formed in the products in Reaction II;

[1]

(iii) calculate ΔH for Reaction II.

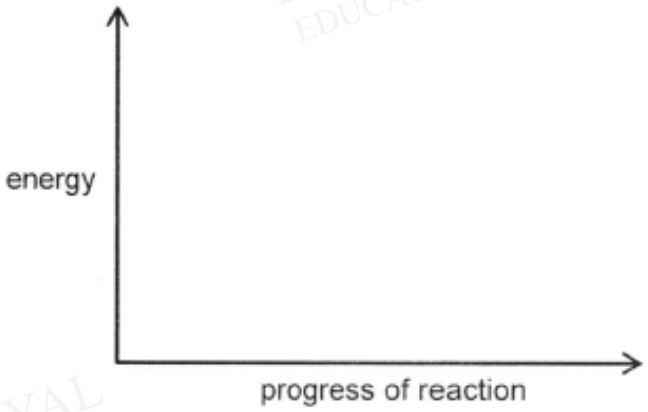
[1]

(c) Which gas, oxygen or fluorine, would be a better oxidant for the hydrazine in rocket fuel? Give a reason for your answer.

.....

..... [1]

(d) Draw an energy profile diagram for the reaction between hydrazine and oxygen.
On your diagram label the product(s), activation energy, E_a, and enthalpy change for the reaction, ΔH.



[2]

(e) Dinitrogen tetroxide (N_2O_4) is sometimes added to hydrazine in rocket fuels.
Oxides of nitrogen are obtained as waste products.

Explain why this can be harmful to the environment.

.....

.....[1]

Q2

When zinc is added to a solution of copper(II) sulfate, a displacement reaction takes place. The equation for this reaction is given below:

$$Zn + CuSO_4 \rightarrow Cu + ZnSO_4 \quad \Delta H = -220 \text{ kJ/mol}$$

(a) Complete the energy profile diagram.

Your diagram should include

- formulae of reactants and products
- enthalpy change of reaction
- activation energy

[2]

(b) In an experiment, 20 cm^3 of copper(II) sulfate solution is reacted with excess zinc powder. The amount of heat evolved is found to be 1.76 kJ.

Calculate the concentration, in mol/dm^3, of the copper(II) sulfate solution used.

[2]

Q3

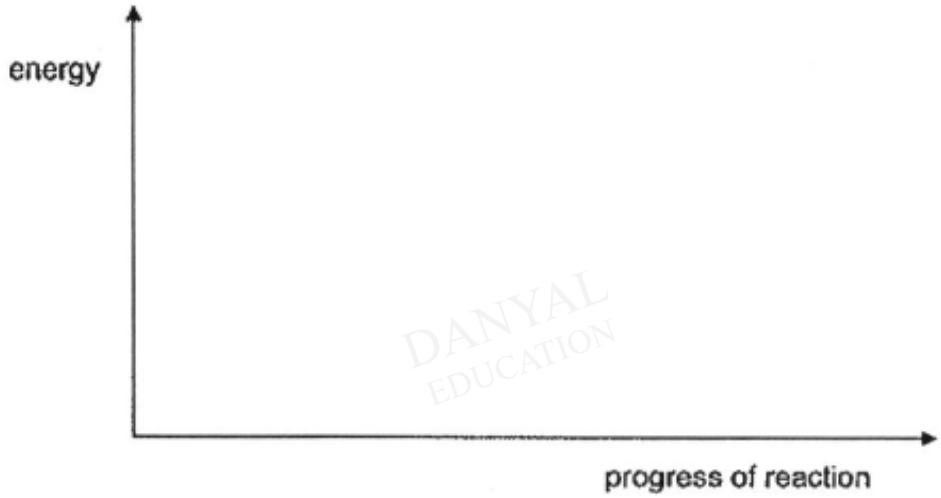
Ozone molecules are continually being broken down and formed in the upper atmosphere.

(a) The equation shows one way in which ozone is formed in the upper atmosphere.

$$O_2(g) + O(g) \rightleftharpoons O_3(g) \qquad \Delta H = -392 \text{ kJ/mol}$$

(i) Draw an energy profile diagram to show the formation of ozone.

Your diagram should show and label
- formulae of reactants and products
- the enthalpy change
- the activation energy for the reaction



[3]

(ii) When one mole of oxygen molecules reacts, 392 kJ of energy is released. Calculate the amount of energy released when 48.0 g of oxygen molecules react.

[2]

(b) Name a pollutant that depletes ozone in the upper atmosphere.

.....[1]

Q4

Liquid petroleum gas (LPG) and ethanol can be used as fuels for cars instead of petrol. LPG contains mainly propane. Table 10.1 shows some information about propane and ethanol.

name	chemical formula	enthalpy change of combustion / kJ per mole	method of manufacture
ethanol		-1367	fermentation of sugar cane
propane		-2220	fractional distillation of crude oil

Table 10.1

(a) Complete the table by filling in the chemical formula of ethanol and propane. [1]

(b) Using the data from the table, show by calculation, that ethanol gives out less energy per kg than propane.

[2]

(c) Show, by calculation or otherwise, that ethanol produces less carbon dioxide than propane when burnt completely.

[2]

(d) Give another reason why using ethanol as a fuel for cars is more environmentally friendly compared to propane.

.....

.....[1]

(e) In a car engine, a spark plug ignites a mixture of air and ethanol. The spark is needed because the combustion of ethanol needs activation energy. Draw an energy profile diagram for the combustion of ethanol. Your diagram should include labels for the enthalpy change and activation energy.

[2]

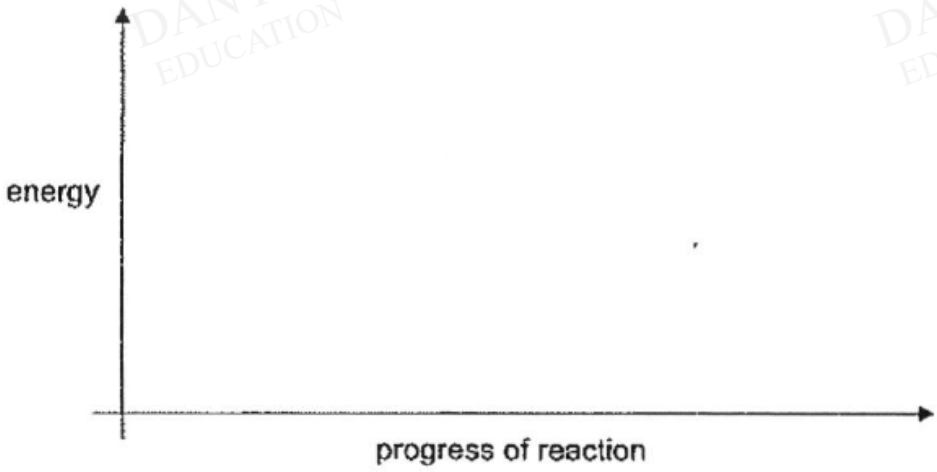
Q5

Ethanol can be oxidised by atmospheric oxygen to form a substance that turns litmus paper red. The reaction is an exothermic process that uses bacteria as a catalyst.

Draw an energy profile diagram to show the effect of the catalyst on the oxidation process.

Your diagram should show and label

- reactants and products,
- the activation energy for the uncatalysed and catalysed reactions,
- the enthalpy change of reaction.

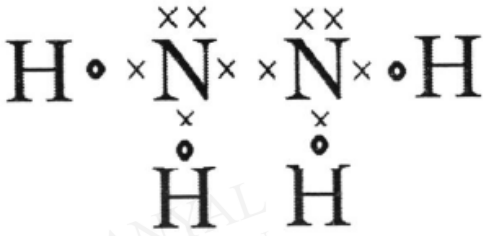


[3]

Answers

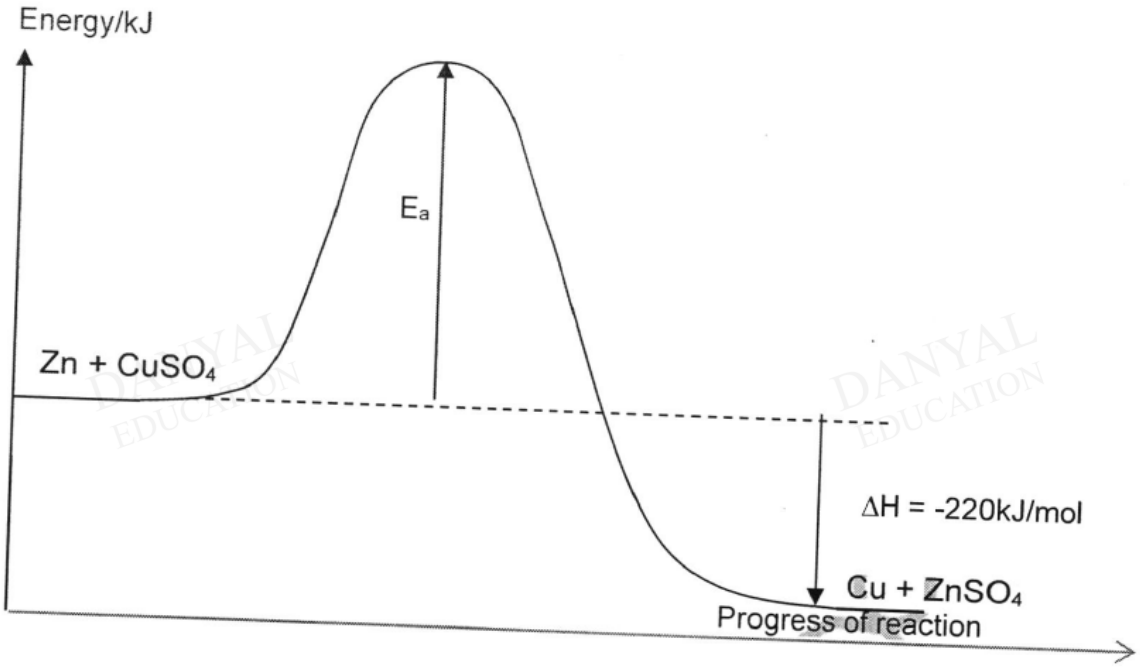
Energy from Chemicals Test 3.0

Q1

(a)	 correct number of electrons for each atom [1] correct number of electrons shared for each bond [1]
(b)	(i) Amount of energy required = 163 + 4(390) + 2(158) = 2036 kJ [1] (ii) Amount of energy released = 945 + 4(565) = 3205 kJ [1] (iii) ΔH for Reaction II = 2039 – 3205 = –1169 kJ [1]
(c)	Fluorine, because the reaction is more exothermic / more energy is released. [1] OR Oxygen, because no pollutants are produced/released [1]
(d)	Correct shape of graph and labelled reactants and products [1] Correct labelled activation energy for the forward reaction + Correct labelled enthalpy change [1] Do not allow double headed arrow head / arrow in wrong direction Note – arrows do not have to start exactly at reactant level and finish exactly at product or maximum of curve Maximum of one mark for an error carried forward for a reaction that is endothermic i.e. enthalpy change mark and activation energy
(e)	Oxides of nitrogen dissolve in rainwater forming acid rain that corrodes limestone structures and building and causes harm to aquatic plants/animals [1]

Q2

(a)



[2

E_a (arrow head upwards) ;
ΔH(arrow head downwards wards) ;
Label reactants & products: ;
3; - [2]
1-2; [1]

(b) No. of moles of $CuSO_4$ = 1.76/220 = 0.008 [1]
Concentration of $CuSO_4$ used = 0.008/(20/1000) = 0.400 mol/dm^3 [1] [2]

Q3

a)(i)
Energy level of reactants higher than products with formulae written;
Enthalpy change labelled correctly;
Activation energy labelled correctly;

a(ii)
Moles of oxygen = 48/(16x2) = 1.5 mol;
Energy released = 1.5 x 392 = 588 kJ;

(b) Chlorofluorocarbons / oxides of nitrogen / nitric oxide;

Q4

(a) C_2H_5OH, C_3H_8

Both must be correct in order to score.

(b) Molar mass of ethanol = 2(12) + 5(1) + 16 + 1 = 46 g/mol

Molar mass of propane = 3(12) + 8(1) = 44 g/mol

Energy given out by 1 kg of ethanol = $\frac{1000}{46}$ x 1367
= 2.97 x 10^4 kJ [1]

Energy given out by 1 kg of propane = $\frac{1000}{44}$ x 2220
= 5.05 x 10^4 kJ [1]

Thus, it can be seen that 1 kg of propane produces more energy than 1 kg of ethanol.

(c) *Any one of the following methods is acceptable.*

<u>Method 1: % of carbon by mass</u>

% of carbon in ethanol = $\frac{2(12)}{46}$ x 100% = 52.2% [1]

% of carbon in propane = $\frac{3(12)}{44}$ x 100% = 81.8% [1]

When burnt completely, propane produces more carbon dioxide gas as it contains a higher percentage of carbon my mass.

<u>Method 2: Number of moles of reactants</u>

Equation for the combustion of ethanol:

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ [1]

Equation for the combustion of propane:

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ [1]

When burnt completely, every one mole of propane produces more carbon dioxide compared to one mole of ethanol.

Method 3: Chemical formula
One molecule of ethanol contains 2 atoms of carbon.
Thus, when one mole of ethanol undergoes combustion, 2 moles of carbon dioxide will be produced. [1]

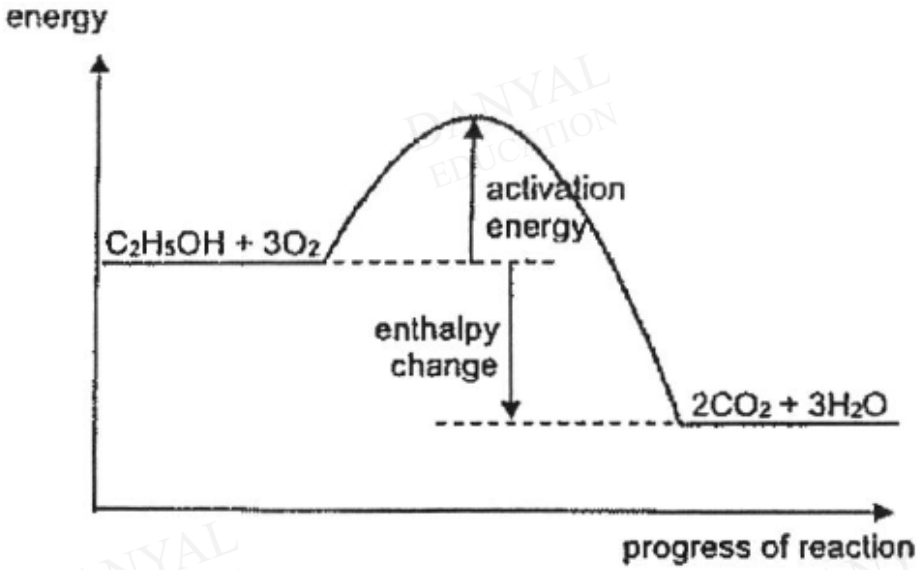
One molecule of propane contains 3 atoms of carbon.
Thus, when one mole of propane undergoes combustion, 3 moles of carbon dioxide will be produced. [1]

When burnt completely, every one mole of propane produces more carbon dioxide compared to one mole of ethanol.

(d) When burnt ethanol does not produce any sulfur dioxide gas but propane does. / Ethanol is carbon neutral as the carbon atoms come from the carbon dioxide in the atmosphere but burning of propane add more carbon dioxide into the atmosphere.

Students must be able to give both sides of the argument, ie. why ethanol is more environmentally friendly compared to propane.

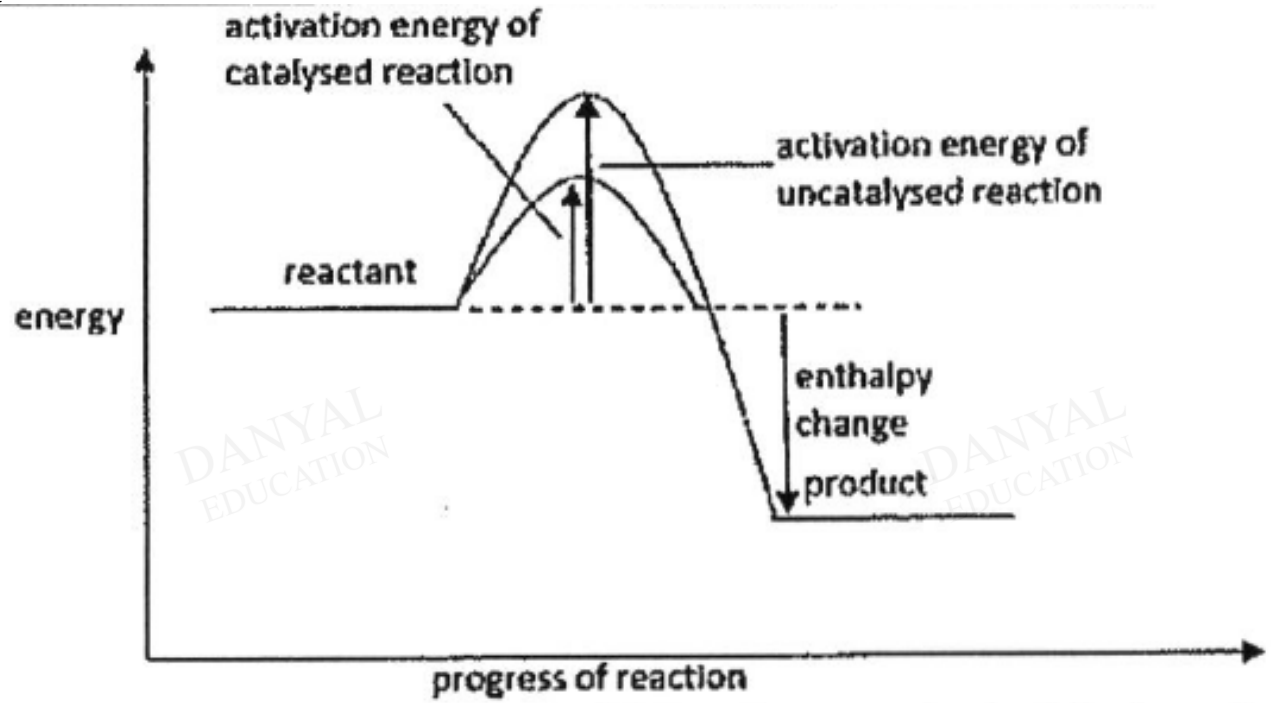
(e)



Energy profile correctly drawn – 1 mk pt
Chemical equation written correctly – 1 mk pt
Activation energy correctly labelled – 1 mk pt
Enthalpy change correctly labelled – 1 mk pt

4 mk pts – [2]
2-3 mk pts – [1]
1 mk pt – [0]

Q5



- show energy of reactants higher than products, label products and reactants [1]
- show correct direction of arrow and label activation energy for catalysed and uncatalysed reaction (activation energy arrows that are too far apart are not credited) [1]
- show correct direction of arrow and label enthalpy change [1]