GCSE Chemistry

Bond Energy Calculations

Question Paper

Time available: 59 minutes
Marks available: 57 marks

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1. This question is about the reaction between hydrogen sulfide (H_2S) and oxygen.

The equation for the reaction is:

$$2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ H_2O(g) + 2\ SO_2(g)$$

(a) What does $H_2O(g)$ represent?

_____

(1)

(b) Calculate the volume of oxygen required to react with 50 cm^3 of hydrogen sulfide.

_____

_____

Volume = _____ cm^3

(1)

(c) **Figure 1** shows part of the reaction profile for the reaction.

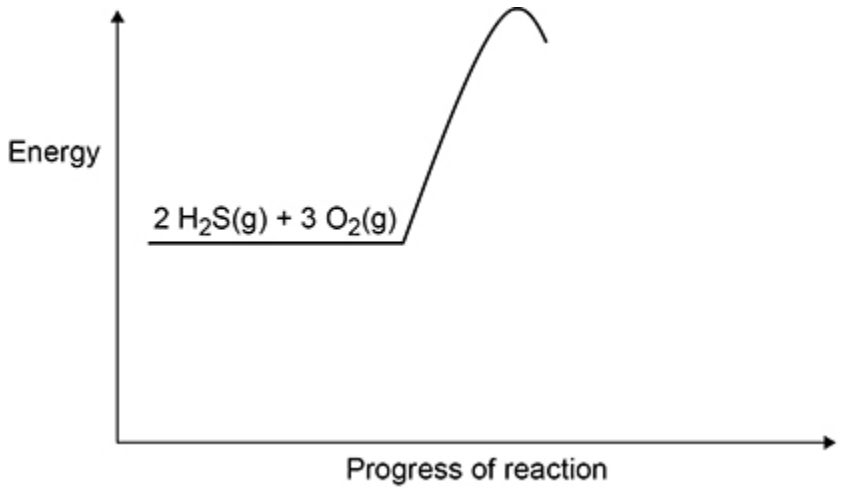
The reaction is exothermic.

Complete **Figure 1**.

You should:

- complete the profile line
- label the activation energy
- label the overall energy change.

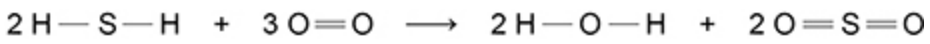
Figure 1



(3)

(d) **Figure 2** shows the displayed formula equation for the reaction of hydrogen sulfide with oxygen.

Figure 2



The table below shows some of the bond energies.

Bond	H — S	O = O	H — O	S = O
Energy in kJ/mol	364	498	464	**X**

In the reaction the energy released forming new bonds is 1034 kJ/mol greater than the energy needed to break existing bonds.

Calculate the bond energy **X** for the bond.

Use **Figure 2** and the table above.

X = _____kJ/mol

(5)

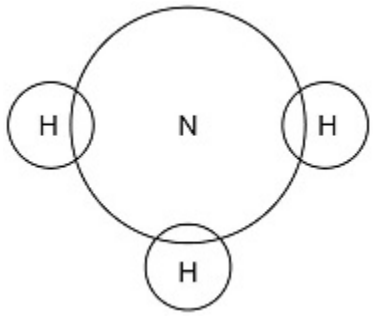
(Total 10 marks)

2. This question is about ammonia, NH_3

(a) Complete the dot and cross diagram for the ammonia molecule shown in **Figure 1**.

Show only the electrons in the outer shell of each atom.

Figure 1



(2)

(b) Give **one** limitation of using a dot and cross diagram to represent an ammonia molecule.

_____

_____

(1)

(c) Explain why ammonia has a low boiling point.

You should refer to structure and bonding in your answer.

_____

_____

_____

_____

_____

_____

(3)

Ammonia reacts with oxygen in the presence of a metal oxide catalyst to produce nitrogen and water.

(d) Which metal oxide is most likely to be a catalyst for this reaction?

Tick (✓) **one** box.

CaO ☐

Cr_2O_3 ☐

MgO ☐

Na_2O ☐

(1)

Figure 2 shows the displayed formula equation for the reaction.

Figure 2

The table shows some bond energies.

Bond	N — H	O = O	N ≡ N	O — H
Bond energy in kJ/mol	391	498	945	464

(e) Calculate the overall energy change for the reaction.

Use **Figure 2** and the table.

Overall energy change = _____ kJ/mol

(3)

(f) Explain why the reaction between ammonia and oxygen is exothermic.

Use values from your calculation in part (e).

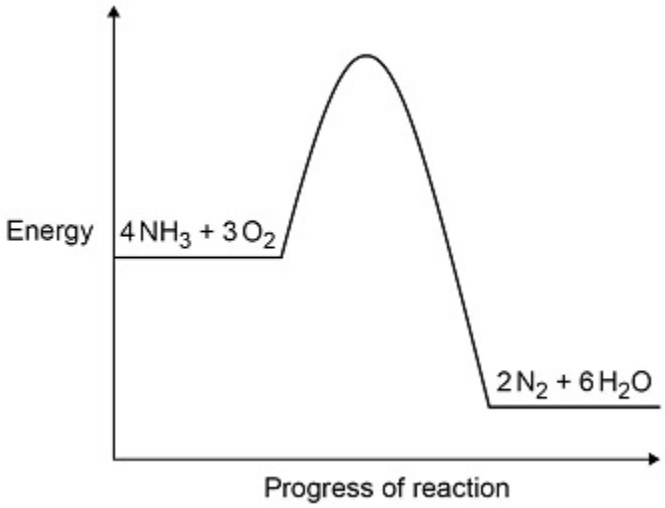
(2)

(g) **Figure 3** shows the reaction profile for the reaction between ammonia and oxygen.

Complete **Figure 3** by labelling the:

- activation energy
- overall energy change.

Figure 3

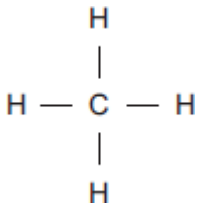


(2)

(Total 14 marks)

3. Methane (CH_4) is used as a fuel.

(a) The displayed structure of methane is:



Draw a ring around a part of the displayed structure that represents a covalent bond.

(1)

(b) Why is methane a compound?

Tick (✓) **one** box.

Methane contains atoms of two elements, combined chemically. ☐

Methane is not in the periodic table. ☐

Methane is a mixture of two different elements. ☐

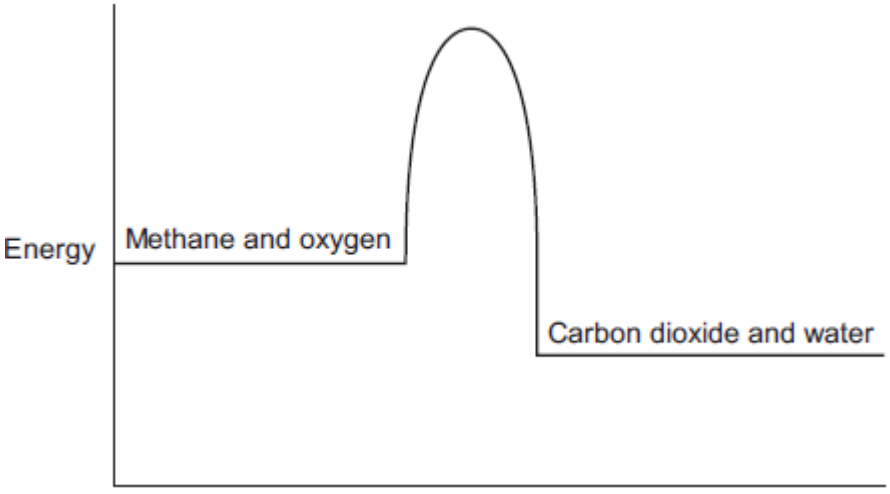
(1)

(c) Methane burns in oxygen.

(i) The diagram below shows the energy level diagram for the complete combustion of methane.

Draw and label arrows on the diagram to show:

- the activation energy
- the enthalpy change, ΔH.



(2)

(ii) Complete and balance the symbol equation for the complete combustion of methane.

$$CH_4 + \_\_\_\_\_ \longrightarrow CO_2 + \_\_\_\_\_$$

(2)

(iii) Explain why the **incomplete** combustion of methane is dangerous.

_____

_____

_____

_____

(2)

(iv) Explain why, in terms of the energy involved in bond breaking and bond making, the combustion of methane is exothermic.

_____

_____

_____

_____

_____

_____

(3)

(d) Methane reacts with chlorine in the presence of sunlight.

The equation for this reaction is:

Some bond dissociation energies are given in the table.

Bond	**Bond dissociation energy in kJ per mole**
C−H	413
C−Cl	327
Cl−Cl	243
H−Cl	432

(i) Show that the enthalpy change, ΔH, for this reaction is −103 kJ per mole.

(3)

(ii) Methane also reacts with bromine in the presence of sunlight.

This reaction is less exothermic than the reaction between methane and chlorine.

The enthalpy change, ΔH, is −45 kJ per mole.

What is a possible reason for this?

Tick (✓) **one** box.

CH_3Br has a lower boiling point than CH_3Cl ☐

The C−Br bond is weaker than the C−Cl bond. ☐

The H−Cl bond is weaker than the H−Br bond. ☐

Chlorine is more reactive than bromine. ☐

(1)

(Total 15 marks)

4. The equation for the reaction of ethene and bromine is:

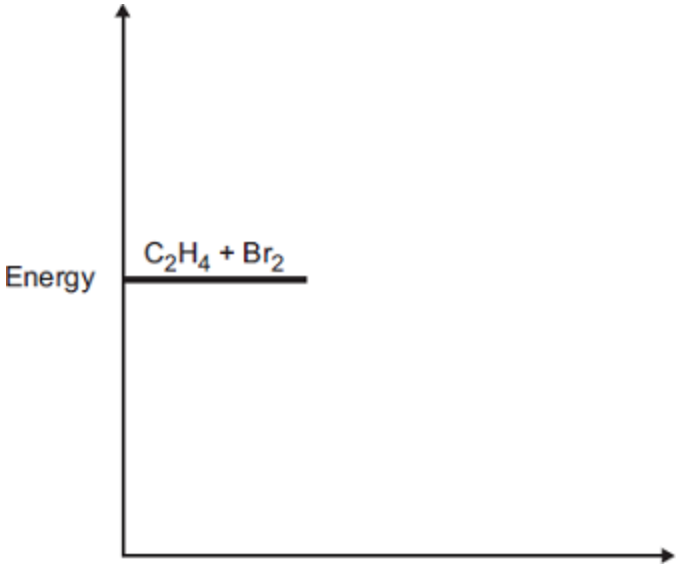
$$C_2H_4(g) + Br_2(l) \longrightarrow C_2H_4Br_2(l)$$

The reaction is exothermic.

(a) Complete the energy level diagram.

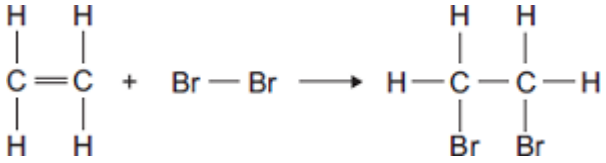
You should label:

- the activation energy
- the enthalpy change (ΔH).



(3)

(b) (i) The equation for the reaction can be represented as:



Bond	**Bond dissociation energy in kJ per mole**
C — H	413
C = C	614
Br — Br	193
C — C	348
C — Br	276

Use the bond dissociation energies in the table to calculate the enthalpy change (ΔH) for this reaction.

Enthalpy change (ΔH) = _____ kJ per mole

(3)

(ii) The reaction is exothermic.

Explain why, in terms of bonds broken and bonds formed.

(2)

(Total 8 marks)

5. (a) Which sub-atomic particles are present in the nucleus of an atom?

_____ and _____

(2)

(b) There are two isotopes of the element chlorine:

$^{35}_{17}Cl$ $^{37}_{17}Cl$

Describe, in terms of sub-atomic particles, **one** similarity and **one** difference between atoms of the two isotopes of chlorine.

Similarity _____

_____

Difference _____

_____

(2)

(c) Chlorine reacts with hydrogen to produce hydrogen chloride.

(i) The table shows the values of some bond dissociation energies.

Bond	**H — H**	**Cl — Cl**	**H — Cl**
Dissociation energy in kJ per mole	436	242	431

Use the values in the table to calculate the enthalpy change (ΔH) for the reaction.

$$H_2(g) + Cl_2(g) \longrightarrow 2\ HCl(g)$$

_____

_____

_____

_____

_____

Enthalpy change (ΔH) = _____ kJ per mole

(3)

(ii) Hydrogen also reacts with fluorine.

$H_2(g) + F_2(g) \longrightarrow 2\ HF(g)$ $\quad \Delta H = -538$ kJ per mole

Draw an energy level diagram for this reaction.

Include on your diagram labels to show:

- the reactants and the products
- the overall enthalpy change (ΔH)
- the activation energy.

(3)

(Total 10 marks)