Bond energies

Worked solutions

GCSE science calculations

This topic online

1 **Higher tier**

In a reaction:

- the energy needed to break all the bonds in the reactants is 2648 kJ/mol
- the energy released making all the bonds in the products is 2391 kJ/mol.

a. Calculate the overall energy change for the reaction.

b. Is the reaction exothermic or endothermic?

(2 marks)

a)

Energy change = bonds broken − bonds made

energy change = 2648 − 2391

+257 kJ/mol

b)

positive, so energy is taken in

endothermic

2 **Higher tier**

Hydrogen reacts with iodine vapour to make hydrogen iodide.

H-H + I-I → 2 H-I

Bond	Bond energy in kJ/mol
H-H	436
I-I	151
H-I	299

Calculate the overall energy change for this reaction.

(3 marks)

Break 1 H-H and 1 I-I

break = 436 + 151 = 587 kJ

Make 2 H-I

make = 2 × 299 = 598 kJ

Energy change = bonds broken − bonds made

energy change = 587 − 598

−11 kJ/mol

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3 **Higher tier**

In a hot car engine, nitrogen and oxygen from the air react to make nitrogen monoxide.

N≡N + O=O → 2 N=O

Bond	Bond energy in kJ/mol
N≡N	945
O=O	498
N=O	607

a. Calculate the overall energy change for this reaction.

b. Explain how your answer shows the reaction is endothermic.

(3 marks)

a)

Break 1 N≡N and 1 O=O

break = 945 + 498 = 1443 kJ

Make 2 N=O

make = 2 × 607 = 1214 kJ

Energy change = bonds broken - bonds made

energy change = 1443 - 1214

+229 kJ/mol

b)

positive: more energy in (breaking) than out (making)

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4 **Higher tier**

In sunlight, methane reacts with chlorine.

$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

A molecule of CH_4 has 4 C-H bonds. A molecule of CH_3Cl has 3 C-H bonds and 1 C-Cl bond.

Bond	Bond energy in kJ/mol
C-H	412
Cl-Cl	243
C-Cl	346
H-Cl	431

Calculate the overall energy change for this reaction. (3 marks)

Break 4 C-H and 1 Cl-Cl

break = (4 x 412) + 243 = 1891 kJ

Make 3 C-H, 1 C-Cl and 1 H-Cl

make = (3 x 412) + 346 + 431 = 2013 kJ

Energy change = bonds broken - bonds made

energy change = 1891 - 2013

-122 kJ/mol

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5 **Higher tier**

Hydrogen reacts with bromine.

H-H + Br-Br → 2 H-Br

Bond	Bond energy in kJ/mol
H-H	436
Br-Br	193
H-Br	366

a. Calculate the overall energy change for this reaction in kJ/mol.

b. Calculate the energy released when 0.40 mol of hydrogen reacts. Give your answer in joules, in standard form.

(4 marks)

a)

break = 436 + 193 = 629 kJ

make = 2 × 366 = 732 kJ

Energy change = bonds broken - bonds made

energy change = 629 - 732

-103 kJ/mol

b)

103 kJ released per 1 mol of hydrogen

energy = 0.40 × 103 = 41.2 kJ

1 kJ = 1000 J

energy = 41.2 × 1000 = 41 200 J

4.12×10^4 J

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6 **Higher tier**

Some model aircraft engines burn methanol as a fuel.

$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$

A methanol molecule has 3 C-H bonds, 1 C-O bond and 1 O-H bond. A carbon dioxide molecule has 2 C=O bonds. A water molecule has 2 O-H bonds.

Bond	Bond energy in kJ/mol
C-H	412
C-C	347
C-O	358
C=O	799
O=O	498
O-H	463

Calculate the overall energy change for the reaction as written. (4 marks)

C-C is not in this reaction: ignore it

Break 2 x (3 C-H + 1 C-O + 1 O-H) and 3 O=O

methanol = 2 x ((3 x 412) + 358 + 463) = 4114 kJ

oxygen = 3 x 498 = 1494 kJ

break = 4114 + 1494 = 5608 kJ

Make 4 C=O (2 CO_2 x 2) and 8 O-H (4 waters x 2)

make = (4 x 799) + (8 x 463) = 6900 kJ

Energy change = bonds broken - bonds made

energy change = 5608 - 6900

-1292 kJ/mol

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7 **Higher tier**

Hydrogen reacts with fluorine.

H-H + F-F → 2 H-F

The overall energy change for this reaction is −538 kJ/mol.

Bond	Bond energy in kJ/mol
H-H	436
F-F	158
H-F	*x*

Calculate the bond energy *x* of the H-F bond. (3 marks)

break = 436 + 158 = 594 kJ

Make 2 H-F

make = 2x

Energy change = bonds broken − bonds made

-538 = 594 − 2x

Add 2x and 538 to both sides

2x = 594 + 538

2x = 1132

Divide both sides by 2

x = 1132 ÷ 2

566 kJ/mol

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8 **Higher tier**

Ammonia is being tested as a carbon-free fuel for ships.

$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$

The overall energy change is −1260 kJ/mol. Each ammonia molecule has 3 N-H bonds. Each water molecule has 2 O-H bonds.

Bond	Bond energy in kJ/mol
N-H	391
O=O	498
O-H	463
N≡N	*y*

Calculate the bond energy *y* of the N≡N bond. (3 marks)

Break 12 N-H (4 ammonia x 3) and 3 O=O

break = (12 x 391) + (3 x 498) = 6186 kJ

Make 2 N≡N and 12 O-H (6 waters x 2)

make = 2y + (12 x 463) = 2y + 5556

Energy change = bonds broken - bonds made

-1260 = 6186 - (2y + 5556)

-1260 = 630 - 2y

Add 2y and 1260 to both sides

2y = 630 + 1260

2y = 1890

Divide both sides by 2

y = 1890 ÷ 2

945 kJ/mol

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9 **Higher tier**

Margarine makers add hydrogen to vegetable oils. A simple model of this is the reaction of ethene with hydrogen.

$C_2H_4 + H_2 \rightarrow C_2H_6$

- Ethene has 1 C=C bond and 4 C-H bonds.
- Ethane has 1 C-C bond and 6 C-H bonds.
- The overall energy change is −123 kJ/mol.

Bond	Bond energy in kJ/mol
C=C	*z*
C-C	347
C-H	412
H-H	436

Calculate the bond energy *z* of the C=C bond. (4 marks)

Break 1 C=C, 4 C-H and 1 H-H

break = z + (4 x 412) + 436 = z + 2084

Make 1 C-C and 6 C-H

make = 347 + (6 x 412) = 2819 kJ

Energy change = bonds broken - bonds made

-123 = z + 2084 - 2819

-123 = z - 735

Add 735 to both sides

z = -123 + 735

612 kJ/mol

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10 **Higher tier**

A camping stove burns propane.

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

A propane molecule has 2 C-C bonds and 8 C-H bonds. A carbon dioxide molecule has 2 C=O bonds. A water molecule has 2 O-H bonds.

Bond	Bond energy in kJ/mol
C-C	347
C-H	412
O=O	498
C=O	799
O-H	463

Relative atomic masses (A_r): H = 1, C = 12

The canister holds 0.44 kg of propane.

Calculate the energy released when all the propane in the canister burns. Give your answer in MJ to 2 significant figures. Show your working.

(5 marks)

Break 2 C-C, 8 C-H and 5 O=O

break = (2 x 347) + (8 x 412) + (5 x 498) = 6480 kJ

Make 6 C=O (3 x 2) and 8 O-H (4 x 2)

make = (6 x 799) + (8 x 463) = 8498 kJ

Energy change = bonds broken - bonds made

energy change = 6480 - 8498 = -2018 kJ/mol

0.44 kg = 440 g

Mr of C3H8 = (3 x 12) + (8 x 1) = 44

moles = 440 ÷ 44 = 10 mol

energy released = 10 x 2018 = 20 180 kJ

1 MJ = 1000 kJ

energy = 20 180 ÷ 1000 = 20.18 MJ

20 MJ

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11 **Higher tier**

A city bus company is comparing hydrogen and methane as fuels.

$2H_2 + O_2 \rightarrow 2H_2O$

Bond	Bond energy in kJ/mol
H-H	436
O=O	498
O-H	463

Relative atomic mass (A_r): H = 1

a. Calculate the overall energy change for the equation as written.

b. Calculate the energy released per gram of hydrogen burnt.

c. Burning methane releases 50 kJ per gram. How many times more energy per gram does hydrogen release? Give your answer to 2 significant figures. Show your working.

(5 marks)

a)

Break 2 H-H and 1 O=O

break = (2 x 436) + 498 = 1370 kJ

Make 4 O-H (2 waters x 2)

make = 4 x 463 = 1852 kJ

energy change = 1370 - 1852

-482 kJ/mol

b)

2 mol of H_2, M_r = 2

mass of hydrogen = 2 x 2 = 4 g

energy per gram = 482 ÷ 4

120.5 kJ/g

c)

ratio = 120.5 ÷ 50 = 2.41

2.4

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12 **Higher tier**

Hydrogen peroxide slowly decomposes.

$2H_2O_2 \rightarrow 2H_2O + O_2$

A hydrogen peroxide molecule (H-O-O-H) has 2 O-H bonds and 1 O-O bond.

Bond	Bond energy in kJ/mol
O-H	463
O-O	146
O=O	498

Relative atomic masses (A_r): H = 1, O = 16

A bottle holds 200 g of solution, which contains 6.8 g of hydrogen peroxide.

Calculate the energy released when all the hydrogen peroxide in the bottle decomposes. Give your answer in joules. Show your working.

(5 marks)

Break 2 x (2 O-H + 1 O-O)

break = 2 x ((2 x 463) + 146) = 2144 kJ

Make 4 O-H and 1 O=O

make = (4 x 463) + 498 = 2350 kJ

energy change = 2144 - 2350 = -206 kJ (for 2 mol H_2O_2)

Use 6.8 g of H_2O_2, not the 200 g of solution

Mr of H_2O_2 = (2 x 1) + (2 x 16) = 34

moles = 6.8 ÷ 34 = 0.2 mol

206 kJ is for 2 mol, so 103 kJ per mol

energy = 0.2 x 103

energy = 20.6 kJ

1 kJ = 1000 J

energy = 20.6 x 1000

20 600 J

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