BOND ENERGY CALCULATIONS

1 **6.1.1**

Hydrogen reacts with the halogens to form hydrogen halides.

(a) Bond energy is the amount of energy, in kJ, that must be supplied (endothermic) to break one mole of a bond.

bond	bond energy in kJ / mol
H–H	+436
C*l*–C*l*	+242
H–C*l*	+431

Use the above data to show that the following reaction is exothermic.

H–H + C*l*–C*l* → 2H–C*l*

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..... [3]

----------Marking scheme----------

(a) (total endothermic change = 436 + 242 = +)678 kJ [1]
(total exothermic change = 2 × 431 = –)862 kJ [1]
accept correct sign/supplied/absorbed for endo etc.
accept correct sign/evolved/produced for exo etc.
change for reaction = –184 kJ [1]

not necessary to calculate –184, just show that exo change > than endo
ecf allowed provided negative
–184 kJ scores all 3 marks

6.1.2

Hydrogen reacts with the halogens to form hydrogen halides.

Bond energy is the amount of energy, in kJ, that must be supplied (endothermic) to break one mole of a bond.

bond	bond energy in kJ / mol
H–H	+436
F–F	+158
H–F	+562

Use the above data to show that the following reaction is exothermic.

$$H–H + F–F \rightarrow 2H–F$$

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..... [3]

(total endothermic change = 436 + 158 = +)594 kJ [1]
(total exothermic change = 2 × 562 = –)1124 kJ [1]
accept correct sign/supplied/absorbed for endo etc.
accept correct sign/evolved/produced for exo etc.
change for reaction = –530 kJ [1]

not necessary to calculate –530, just show that exo change > than endo
ecf allowed provided negative
–530 kJ scores all 3 marks

6.1.3

(a) The equilibrium mixture leaving the reaction chamber contains 15% ammonia. Suggest how the ammonia could be separated from the mixture.

	boiling point / °C
hydrogen	–253
nitrogen	–196
ammonia	–33

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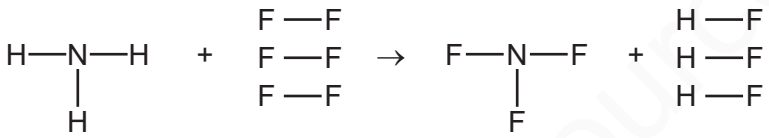
..... [2]

(b) Ammonia is used to make nitrogen trifluoride, NF_3.
Nitrogen trifluoride is essential to the electronics industry. It is made by the following reaction.



Determine if the above reaction is exothermic or endothermic using the following bond energies and by completing the following table. The first line has been done as an example.
Bond energy is the amount of energy, in kJ / mole, needed to break or make one mole of the bond.

bond	bond energy in kJ / mole
N – H	390
F – F	155
N – F	280
H – F	565

bond	energy change / kJ
N – H	(3 × 390) = 1170
F – F	
N – F	
H – F	

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..... [4]

(a) lower the temperature (1)
only ammonia will liquefy (1)
OR
add water (1)
only ammonia will dissolve (1)
OR
increase pressure (1)
only ammonia will liquefy (1) [2]

(b) second line +3 × 155 = + 465
third line –3 × 280 = (–)840
fourth line –3 × 565 = (–)1695
all **three** correct (2)
two correct (1)

1170 + 465 = 1635
840 + 1695 = 2535
both numerically correct (1)
exothermic reaction with some reasoning (1) [4]

6.1.4

(i) Complete the following table that describes the bond breaking and forming in the reaction between nitrogen and hydrogen to form ammonia.

bonds	energy change /kJ	exothermic or endothermic
1 mole of N ≡ N broken	+945	.....
3 moles of ..... broken	+1308	.....
6 moles of N – H formed	-2328	.....

[3]

(ii) Explain, using the above data, why the forward reaction is exothermic.

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..... [2]

(i) H—H **[1]**
endothermic **[1]**
endothermic **[1]**
exothermic

(ii) More heat given out than taken in **[1]**
–2328 + 945 + 1308 = –75(kJ) **[1]**

OR More heat given out bond forming than taken in bond breaking **[2]**
Must mention bond breaking and forming **[2]**

6.1.5

(i) What is the difference between an endothermic and an exothermic reaction?

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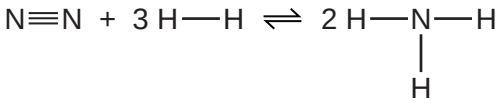
..... [1]

(ii) Bond breaking is an endothermic process. Bond energy is the amount of energy needed to break or form one mole of the bond. Complete the table and explain why the forward reaction is exothermic.



bond	bond energy kJ / mol	energy change kJ	exothermic or endothermic
N≡N	944	+944	endothermic
H—H	436	3 × 436 = +1308	
N—H	388		

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..... [3]

(i) endothermic takes in / absorbs / uses / needs / gains energy / heat **and** exothermic gives out / loses energy / heat; [1]

(ii) 2328 (ignore + or –) / 6 × 388 (not evaluated); [1]

944 + 1308 / 2252 **and** endothermic and exothermic in table; [1]

2328>2252 or (–) 76 kJ; [1]

or energy of products / RHS > reactants / LHS
or energy needed to break bonds < energy given out on formation of bonds.