CALCULATING BOND ENERGIES

1 **(a)** Astatine is at the bottom of Group VII. Use your knowledge of the properties of the halogens to

(i) predict the physical state of astatine at room temperature and pressure,

..... [1]

(ii) write a chemical equation for the reaction between sodium and astatine.

..... [2]

(b) Iodine reacts with chlorine. The chemical equation is shown.

$$I_2 + Cl_2 \rightarrow 2ICl$$

Use the bond energies to answer the questions.

bond	bond energy in kJ/mol
I–I	151
Cl–Cl	242
I–Cl	208

(i) Calculate the total amount of energy required to break the bonds in 1 mole of I_2 and 1 mole of Cl_2.

..... kJ [1]

(ii) Calculate the total amount of energy given out when the bonds in 2 moles of ICl are formed.

..... kJ [1]

(iii) Use your answers to **(d)(i)** and **(d)(ii)** to calculate the overall energy change for the reaction.

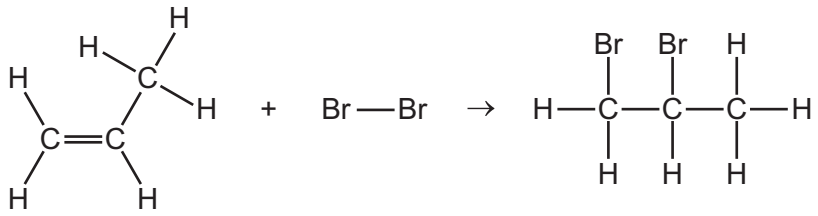
$$I_2 + Cl_2 \rightarrow 2ICl$$

..... kJ/mol [1]

MARKING SCHEME:

(a)	(i)	solid	**1**
	(ii)	$2Na + At_2 \rightarrow 2NaAt$ **M1** formula of NaAt **M2** equation fully correct	**2**
(b)	(i)	393 (kJ)	**1**
	(ii)	416 (kJ)	**1**
	(iii)	–23 (kJ / mol)	**1**

2 Propene also reacts with bromine.



Use the bond energies in the table to calculate the energy change, ΔH, for the reaction.

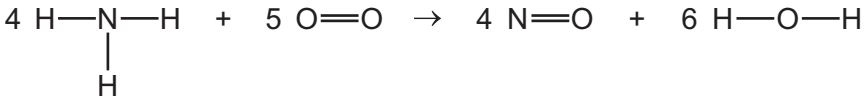
	C–H	C–C	Br–Br	C–Br	C=C
bond energy in kJ / mol	412	348	193	285	611

energy change = ... kJ / mol [3]

MARKING SCHEME:

(energy required to break bonds =) 3624	**1**
(energy given out when bonds made =) 3738	**1**
–114 (kJ / mol)	**1**

3 The chemical equation for the reaction can be represented as shown.



Use the bond energies in the table to calculate the energy change, in kJ/mol, which occurs when **one** mole of NH_3 reacts.

bond	N–H	O=O	N=O	O–H
bond energy in kJ/mol	391	498	587	464

- Energy needed to break bonds.

..... kJ

- Energy released when bonds are formed.

..... kJ

- Energy change when **one** mole of NH_3 reacts.

energy change = ... kJ/mol
[4]

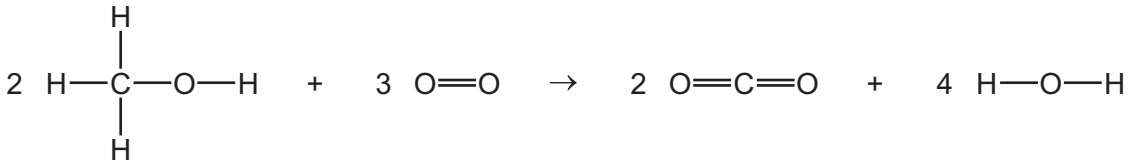
MARKING SCHEME:

	M1 Bonds broken [4 × 3 × 391] + [5 × 498] = 4692 + 2490 = 7182 **M2** Bonds formed [4 × 587] + [12 × 464] = 2348 + 5568 = 7916 **M3** Energy change = 7182 – 7916 = –734 **M4** = **M3** / 4 = –734 / 4 = –183.5	**4**

4 The chemical equation for the complete combustion of methanol, CH_3OH, is shown.

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

The equation can be represented as shown.



Use the bond energies in the table to determine the energy change, ΔH, for the complete combustion of **one** mole of methanol.

bond	bond energy in kJ / mol
C–H	410
C–O	360
O–H	460
O=O	500
C=O	805

- energy needed to break bonds

..... kJ

- energy released when bonds are formed

..... kJ

- energy change, ΔH, for the complete combustion of **one** mole of methanol

..... kJ / mol
[4]

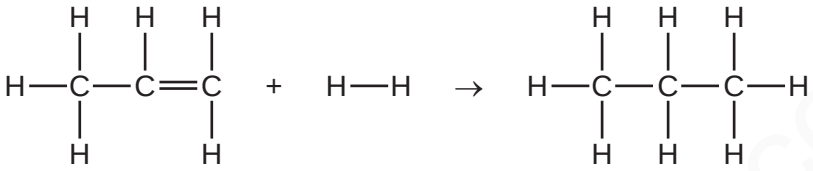
MARKING SCHEME:

	–650 kJ / mol **M1** bonds broken 2 × ((3 × 410) + 360 + 460) + (3 × 500) 2 × (1230 + 360 + 460) + 1500 2 × 2050 + 1500 4100 + 1500 = 5600 **M2** bonds formed (2 × (2 × 805)) + (4 × (2 × 460)) 2 × 1610 + 4 × 920 3220 + 3680 = 6900 **M3** = **M1** – **M2** energy change of reaction = 5600 – 6900 = –1300 **M4** = **M3** / 2	**4**

5 Bond energy is the amount of energy, in kJ, which must be supplied to break one mole of the bond.

bond	bond energy in kJ / mol
H—H	+436
C═C	+610
C—C	+346
C—H	+415

Use the data in the table to show that the following reaction is exothermic.



.....

.....

..... [3]

bonds broken
H-H +436 (kJ/mol) C=C +610 = +1046 (kJ/mol) [1]
bonds formed
2C-H –415 × 2 kJ/mol C-C –346 = –1176 (kJ/mol) [1]
–130 kJ/mol / more energy released than absorbed [1]
or:
bonds broken
3882 (kJ/mol) [1]
bonds formed
4012 (kJ/mol) [1]
–130 kJ/mol / more energy released than absorbed [1]
allow: ecf for final mark as long as the answer is not positive
note: units not necessary