Marks 6

- An "excimer laser" is a type of ultraviolet laser used for lithography, micromachining and eye surgery. In one type of laser, an electrical discharge through HCl and Xe in a helium buffer gas yields metastable XeCl molecules, described like an ion pair. These then emit 308 nm light and dissociate into Xe and Cl atoms.

element	Ionisation energy / kJ mol^{-1}	Electron affinity / kJ mol^{-1}
Xe	1170.4	–
Cl	1251.1	–349

What energy, in eV, is required to convert a pair of Xe and Cl atoms into Xe^+ and Cl^- ions?

To form Xe^+ requires 1170.4 kJ mol^{-1} and in forming Cl^-, 349 kJ mol^{-1} is released. The total energy change is therefore:

total energy change = [(+1170.4) + (-349)] kJ mol^{-1} = +821.4 kJ mol^{-1}

or

total energy per pair of atoms = (+821.4 kJ mol^{-1}) / (6.022 × 10^{23} mol^{-1})
= 1.364 × 10^{-18} J

As 1 eV = 1.602 × 10^{-19} J, this corresponds to:

total energy per pair of atoms = (1.364 × 10^{-18}) / (1.602 × 10^{-19}) eV
= 8.51 eV

Answer: **8.51 eV**

What energy (in eV) is released when the XeCl molecules emit ultraviolet light?

A wavelength of 308 nm corresponds to an energy of:

$$E = hc / \lambda$$
$$= (6.626 \times 10^{-34}\ \text{J s}) \times (2.998 \times 10^{8}\ \text{m s}^{-1}) / (308 \times 10^{-9}\ \text{m})$$
$$= 6.45 \times 10^{-19}\ \text{J}$$

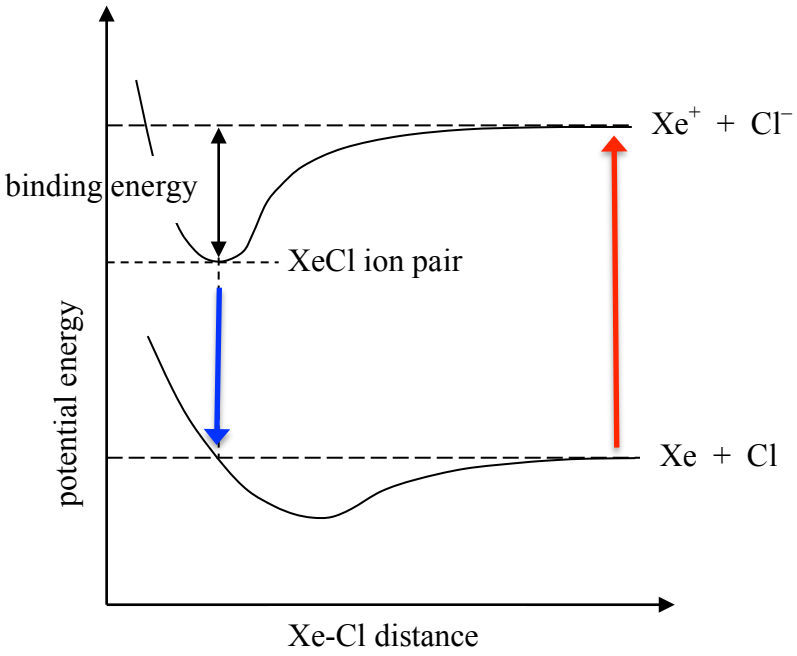
As 1 eV = 1.602 × 10^{-19} J, this corresponds to:

$$E = (6.45 \times 10^{-19}) / (1.602 \times 10^{-19})\ \text{eV}$$
$$= 4.03\ \text{eV}$$

Answer: **4.03 eV**

THIS QUESTION CONTINUES ON THE NEXT PAGE.

Marks 4



What is the binding energy (in J) of the XeCl ion pair?

The binding energy of the ion pair is shown by the double headed arrow on the diagram above. This is the *difference* between the energy needed to form a pair of Xe^+ and Cl^- ions (8.51 eV; red arrow above) and the energy released when XeCl molecules emit light (4.03 eV; blue arrow above).

Binding energy = (8.51 – 4.03) eV = 4.48 eV

As 1 eV = 1.602×10^{-19} J, this corresponds to:

Binding energy = $(4.48 \times 1.602 \times 10^{-19})$ eV
= 7.18×10^{-19}

Answer: **7.18×10^{-19} J**

If the binding is electrostatic, what is the approximate equilibrium bond length of XeCl if the binding energy is given by the Coulomb formula: $E = \dfrac{q_1 q_2}{4\pi\varepsilon_0 r}$?

For Xe^+, $q = 1.602 \times 10^{-19}$ C. For Cl^-, $q = -1.602 \times 10^{-19}$ C.

Using $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 J^{-1} m^{-1} and $E = 7.18 \times 10^{-19}$ J:

$r = q_1 q_2 / 4\pi\varepsilon_0 E$
$= (1.602 \times 10^{-19}\ C)^2 / (4\pi \times 8.854 \times 10^{-12}\ C^2\ J^{-1}\ m^{-1} \times 7.18 \times 10^{-19}\ J)$
$= 3.21 \times 10^{-10}$ m = 321 pm or 3.21 Å

Answer: **321 pm or 3.21 Å**