7 When some substances are in the solid state, they exist as positively-charged and negatively-charged ions arranged in a cubic lattice, as illustrated in Fig. 7.1.

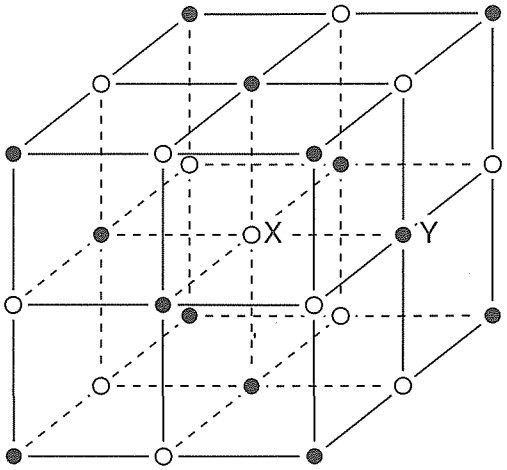

Fig. 7.1

A starting point for the understanding of lattice energies is to consider the potential energy E_P between two ions X and Y.

Fig. 7.2 shows the variation with distance r between X and Y of E_P.

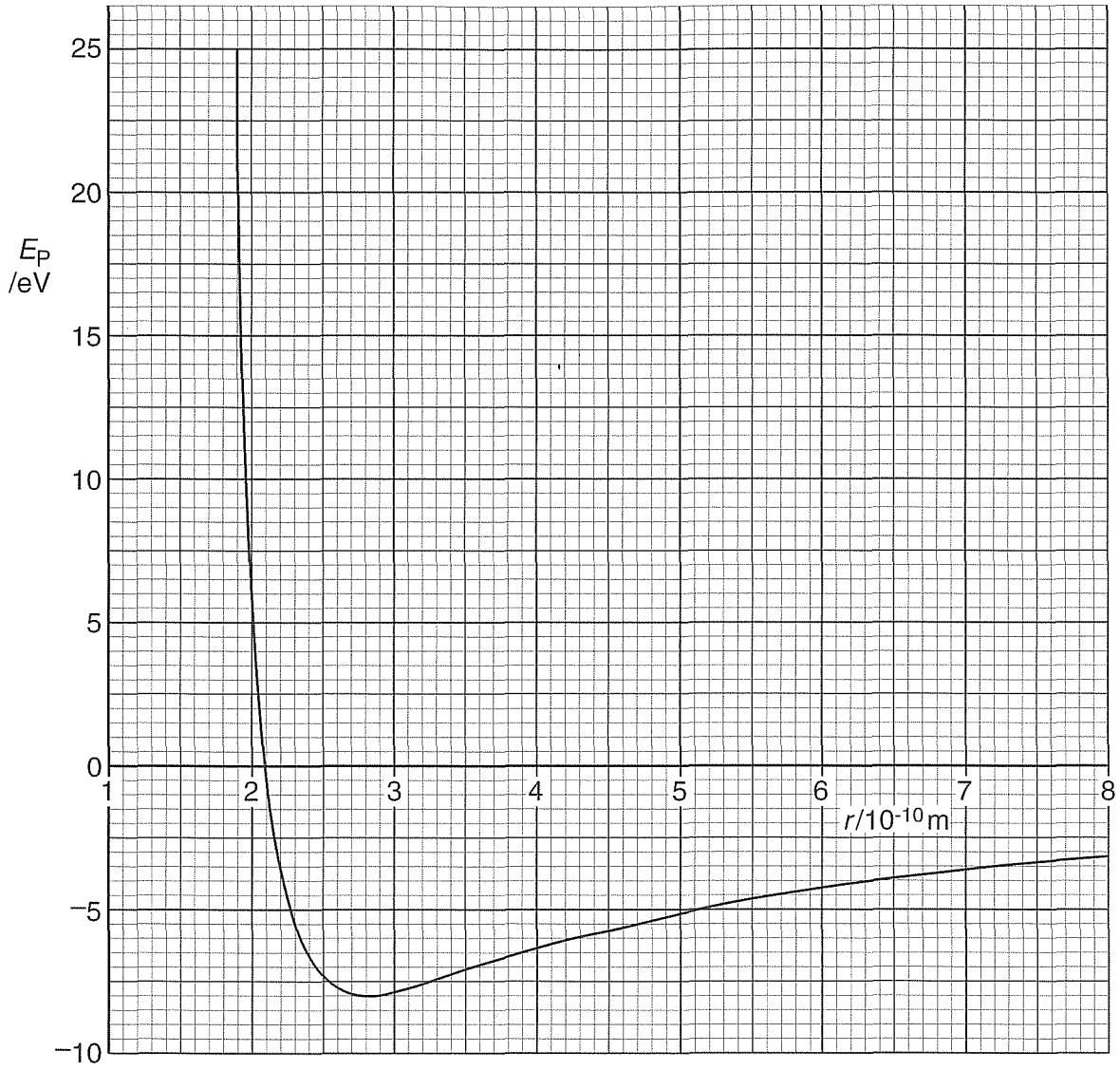

Fig. 7.2

(a) (i) The gradient G of the graph varies with the distance r. Show that, starting from the definition of *work done*, for any value of r the magnitude of the force F between X and Y is given by the expression

$$F = G.$$

.....

.....

..... [2]

(ii) Suggest how Fig. 7.2 indicates that, for some values of r, the force between X and Y is attractive and, for other distances, the force is repulsive.

.....

.....

..... [2]

(iii) Use Fig. 7.2 and the expression in **(i)** to determine the magnitude of the force, in newton, for values of the distance r equal to

1. 2.8×10^{-10} m,

force = ... N [1]

2. 5.0×10^{-10} m.

force = ... N [3]

(b) The variation with distance r of the potential energy E_P may be represented by the expression

$$E_P = -\frac{A}{r} + \frac{B}{r^8},$$

where A and B are constants.

By reference to Fig. 7.2, state two features of the force represented by the term $\frac{B}{r^8}$ in this expression.

1. .....

.....

2. .....

..... [2]

(c) Fig. 7.3 shows part of Fig. 7.2, drawn on a larger scale.

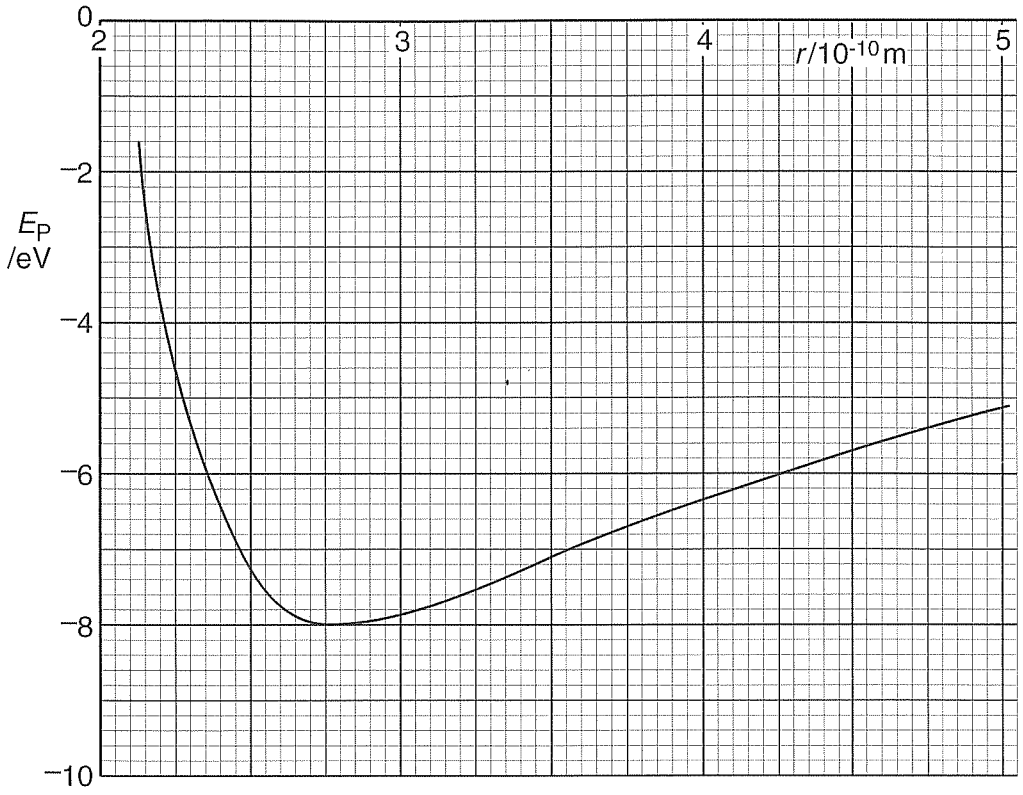

Fig. 7.3

Thermal energy of the ions causes them to vibrate.

The ions have a total energy of –6.0 eV.

(i) Use Fig. 7.3 to determine, for these ions,

1. the values of r between which they vibrate,

minimum value of r = ... m

maximum value of r = ... m [2]

2. the kinetic energy of the ions at distance $r = 3.5 \times 10^{-10}$ m.

kinetic energy = ... eV [2]

(ii) State why, although the ions are oscillating, their motion is **not** simple harmonic.

.....

..... [1]

(d) By reference to Fig. 7.3, suggest why the dimensions of the whole lattice increase as it is heated.

.....

.....

.....

..... [3]