1. Identify the Bravais lattice and describe the basis or motif of each of the following crystal models showed in the pictures:
   a) NaCl (rock salt)
   b) CsCl,
   c) diamond,
   d) ZnS (blende),
   e) CaF$_2$ (flurite)
   f) SrTiO$_3$ (perovskite)
a) NaCl – Cubic (F): Na and Cl
b) CaF2 – Cubic (F): 1 Ca and 2 F
c) Diamond – Cubic (F): C and C
d) ZnS (blende) – Cubic (F): Zn and S
e) SrTiO3 – Cubic (P): 1Ca, 1Ti and 3O
f) CsCl – Cubic (P): Cs and Cl

2. For the crystal structures a), b) and f) at 1, describe the atomic positions and draw a projection of the atom planes.

a) /picture (a) 
   NaCl → Cl: 0,0,0 
   Na: ½ ½ ½

b) /picture (b) 
   CaF2 → Ca: 0 0 0 
   F: ¼ ¼ ¼

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b) / picture (f)

\[
\text{CsCl} \rightarrow \text{Cs: 0 0 0}
\]
\[
\text{Cl: } \frac{1}{2} \frac{1}{2} \frac{1}{2}
\]

f) / picture (e)

\[
\text{SrTiO}_3 \rightarrow \text{Ti: 0,0,0}
\]
\[
\text{Sr: } \frac{1}{2} \frac{1}{2} \frac{1}{2}
\]
\[
\text{O: } \frac{1}{2} , 0 , 0 (0, \frac{1}{2},0; 0, 0, \frac{1}{2})
\]
3. The drawings in the figures below show patterns of points distributed in orthorhombic –shaped unit cells. Identify to which, if any, of the orthorhombic structure Bravais lattice, P, C, I or F each pattern of points corresponds. (Hint: it is helpful to sketch plans of several unit cells, which will show more clearly the patterns of points, and then to outline (if possible) a P, C, I, or F unit cell)

![Bravais lattices and crystal systems](image)

a) Is orthorhombic C
b) It is not a Bravais lattice because the points do not all have an identical environment
c) Is orthorhombic P (two primitive cells are drawn together)

4. The unit cell of several orthorhombic structures is described below. Draw planes of each and identify the Bravais lattice, P, C, I or F
a) One atom per unit cell located at (x’, y’, z’)
b) Two atoms per unit cell of the same type located at (0, ½, 0) and (1/2, 0, ½)
c) Two atoms per unit cell, one type located at (0, 0, z’) and (½, ½, z’) and the other type at (00(1/2+z’)) and (1/2 ½ (1/2+z’))
(hint: draw planes of several unit cells and relocate the origin of the axes, x’, y’, z’ should be taken as small (non-integral) fractions of the cell edge length)

a) Is orthorhombic P (relocate the origin at x’y’z’)
b) Is orthorhombic I (relocate the origin at 0, ½, 0)
c) Is orthorhombic C (relocate the origin at 00z'; the motif is two atoms, one of each type)

5. A metal is found to have BCC structure, a lattice constant of 3.31 Å and a density of 16.6 g/cm³. Determine the atomic weight of this element.

For BCC structure Z=2
V = a³ = 36.26 Å³.

\[ D = \frac{FW \times Z \times 1.66}{V} \text{ (g/cm}^3\text{)} \Rightarrow \]
\[ F_w = \frac{D \times V}{1.66 \times 2} = 181.3 \text{ (g/mol)} \]

6. Determine the first and second nearest neighbor distance for Ni (FCC structure) at 100°C if its density at that temperature is 8.83 g/cm³.

For a FCC structure Z = 4. The first neighbor is on the face diagonal at a distance \( a \frac{\sqrt{2}}{2} \) while the second nearest distance is on the cube corner at distance \( a \) (cube edge)

\[ F_w_{Ni} = 58.7 \text{ g} \]

\[ D = \frac{FW \times Z \times 1.66}{V} \text{ (g/cm}^3\text{)} \Rightarrow \]
\[ V = \frac{4 \times 1.66 \times 58.7}{8.83} = 44.14 \text{ Å} \Rightarrow a = 3.53 \text{ Å} \]

The first nearest neighbors of Ni is at 2.5 Å while the second nearest neighbor is at 3.53 Å.

7. Calculate the volume change (in %) that will occur if (for some reason) a material transforms from BCC to FCC. (Assume hard sphere behavior.)
For BCC: $Z=2$ and the atoms are touching on the cube diagonal $\Rightarrow a\sqrt{3}/2 = 2r \Rightarrow a = 4r/\sqrt{3}$

$V_{BCC} = (4r/\sqrt{3})^3/2 = 6.16r^3$

For FCC: $Z=4$ and the atoms are touching on the face diagonal $\Rightarrow a\sqrt{2}/2 = 2r \Rightarrow a = 4r/\sqrt{2}$

$V_{FCC} = (4r/\sqrt{2})^3/4 = 5.65r^3$

The volume change: $(V_{BCC} - V_{FCC})/V_{BCC} \times 100 = 9\%$

8. a) In how many ways can (mathematical) points be arranged in two (2) dimensions so that every point has identical surroundings? (One possible arrangement is the square distribution of points; if you imagine that this distribution continues to infinity, then every point has neighbors at the same angle)

(b) Sketch the possible arrangements (no more than 20 points each).

(1) $a = b, \alpha = 90^\circ$

(2) $a \neq b, \alpha = 90^\circ$

(3) $a \neq b, \alpha \neq 90^\circ$

(4) $a = b, \alpha \neq 90^\circ$

(5) $a = b, \alpha = 60^\circ$