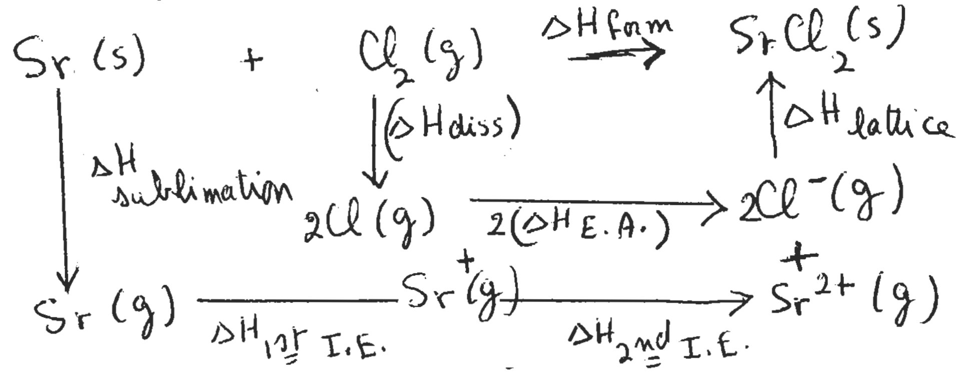
WORKSHEET-SOLIDS

Set A:

1. Indicate the **type of crystalline** solid each of the following would form upon crystallization. Tell what **type of particles** are located at the lattice points and the **types of attractive forces** that exist between the particles.

	Type of crystalline solid	Type of particles at lattice points	Attractive forces between lattice points
SiC	covalent	atoms	covalent bond
HBr	molecular	molecules	Intermolecular forces
Cu	metallic	cations	attraction between sea of electrons and cations
Br_2	molecular	molecules	Intermolecular forces
NH_4ClO_3	ionic	cations and anions	Electrostatic attraction between cations and anions

2. a. Draw Born-Haber cycle for the formation of strontium chloride



b. Use the following data to calculate the enthalpy of formation of strontium chloride. You must write all thermochemical equations for the steps of the cycle.

The enthalpy of sublimation of strontium = + 164 kj/mole

First ionization energy for strontium = + 549 kj/mole

Second ionization energy for strontium = + 1064 kj/mole

The enthalpy of dissociation of chlorine, Cl_2 = + 243 kj/mole

The electron affinity of chlorine, Cl = - 349 kj/mole

Lattice energy of strontium chloride = - 2150 kj/mole Answer= - 828 kj

$Sr(s) \rightarrow Sr(g)$ +164 kj/mole

$Sr(g) \rightarrow Sr^{+}(g)$ +549 kj/mole

$Sr^{+}(g) \rightarrow Sr^{2+}(g)$ + 1064 kj/mole

$Cl_2(g) \rightarrow 2Cl(g)$ + 243 kj/mole

$2Cl + 2e^- \rightarrow 2Cl^-(g)$ 2 moles Cl (-349 kj/mole) = -698 kj

$Sr^{2+}(g) + 2Cl^-(g) \rightarrow SrCl_2(s)$ - 2150 kj/mole

Add: $Sr(s) + Cl_2(g) \rightarrow SrCl_2(s)$

$\Delta H_{form} = \Delta H_{sub} + \Delta H_{1st\ I.E.} + \Delta H_{2nd\ I.E.} + \Delta H_{diss} + 2(\Delta H_{E.A}) + \Delta H_{lattice\ energy}$

= 164 kj + 549 kj + 1064 kj + 233 kj + 2(- 349 kj) - 2150 kj

= -828 kj

3) Crystalline aluminum has cubic structure. The unit edge length is 4.440 x 10 $^{-8}$. The density of solid aluminum is 4.096 g/cm^3. Calculate the number of aluminum atoms in one unit cell. Answer=8.00 atoms/unit cell

$V_{unit\ cell} = (4.440 \times 10^{-8} cm)^3 = 8.750 \times 10^{-23}\ cm^3$

mass of all atoms inside unit cell = Density × $V_{unit cell}$

$= 4.096\ \frac{g}{cm^3} \times 8.750 \times 10^{-23} cm^3$

$= 3.585 \times 10^{-22} g$ Al/unit cell

$3.585 \times 10^{-22} \frac{g\ Al}{unit cell} \left(\frac{1 mole\ Al}{27.00 g\ Al}\right)\left(\frac{6.02 \times 10^{23} atoms\ Al}{1 mole\ Al}\right) = 7.99$ atoms/unit cell

= 8 atoms/unit cell

4) Name the energy, Δ H, in each of the following processes:

a) $2 Cs^+ (g) + O^{2-} (g)$ ——> $Cs_2O (s)$ a) ____________

b) $O (g) + 1 e^-$ ——> $O^- (g)$ b) ____________

c) $2 Cs (s) + 1/2\ O_2 (g)$ ——> $Cs_2O (s)$ c) ____________

Answer: a) Lattice energy b) Electron affinity c) Heat of formation

5) The volume of a manganese atom is 9.21 x 10 $^{-24}$ cm ^{3}. Manganese crystallizes in a face-centered cubic sysrtem. What is the density of manganese?

Answer: 7.34 g/cm^3

① $V_{atom} = \frac{4}{3} \pi r^3$

$r^3 = \frac{V_{atom} (3)}{4 \pi} = \frac{(9.21 \times 10^{-24} cm^3)(3)}{(4)(3.14)} = 2.20 \times 10^{-24} cm^3$

$r = 1.30 \times 10^{-8} cm$

② $\sqrt{2}\ a = 4r$; $a = \frac{4r}{\sqrt{2}} = \frac{4(1.30 \times 10^{-8} cm)}{1.4142} = 3.677 \times 10^{-8} cm$

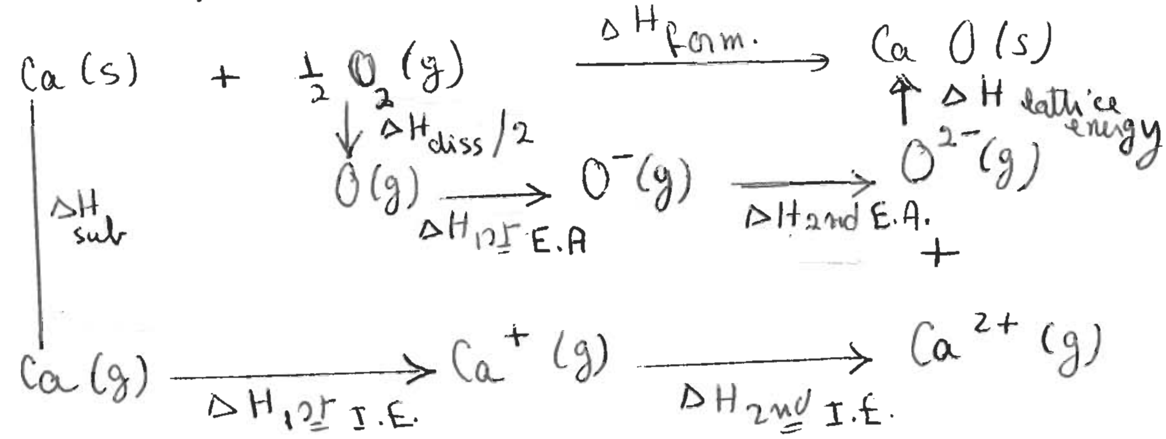
③ mass of all atoms inside unit cell:

$54.94 \frac{g\ Mn}{1 mole\ Mn} \left(\frac{1 mole\ Mn}{6.02 \times 10^{23} atoms\ Mn}\right) 4 atoms = 3.65 \times 10^{-22} g\ Mn$

④ $D = \frac{\text{mass of all atoms inside unit cell}}{a^3} = \frac{3.65 \times 10^{-22} g\ Mn}{(3.677 \times 10^{-8} cm)^3} = 7.34 g/cm^3$

Set B:

1. a. Draw Born-Haber cycle for the formation of calcium oxide.



b. Use the following data to calculate the lattice energy of calcium oxide. You must write all thermochemical equations for the steps of the cycle.
The enthalpy of formation of calcium oxide (solid) = - 636 kj/mole
The enthalpy of sublimation of calcium= + 192 kj/mole
First ionization energy of Ca = + 590 kj/mole
Second ionization energy of Ca= +1145 kj/mole
The enthalpy of dissociation of O_2 (g) = + 494 kj/mole
First electron affinity of O (g) = - 141 kj/mole
Second electron affinity of O (g) = + 845 kj/mole

Answer : -3514 kj

$Ca(s) \rightarrow Ca(g)$ $\Delta H = +192\ kj$

$Ca(g) \rightarrow Ca^{+}(g) + 1e^{-}$ $\Delta H = +590\ kj$

$Ca^{+}(g) \rightarrow Ca^{2+}(g) + 1e^{-}$ $\Delta H = 1145\ kj$

$\frac{1}{2}O_2(g) \rightarrow O(g)$ $\Delta H = 0.5\ mole\ O_2 \left(\frac{494\ kj}{mole}\right)$

$O(g) \rightarrow O^{-}(g)$ $\Delta H = -141\ kj$

$O^{-}(g) \rightarrow O^{2-}(g)$ $\Delta H = +845\ kj$

$Ca^{2+}(g) + O^{2-}(g) \rightarrow CaO(s)$ $\Delta H_{lattice} = ?$

Add: $Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$ $\Delta H_{form} = -636\ kj$

$-636\ kj = +192\ kj + 590\ kj + 1145\ kj + \frac{492}{2}\ kj - 141\ kj + 845\ kj + \Delta H_{lattice}$

$\Delta H_{lattice} = -3514\ kj$

2. $CaCl_2$ (s) crystallizes in a cubic lattice. The unit cell has an edge of 4.77 x 10^{-8} cm. The density of $CaCl_2$ (s) is 6.80 g/cm^3. How many formula units of $CaCl_2$ must there be per unit cell?

Answer: 4 formula units

① $D = \frac{\text{mass of all formula units inside unite cell}}{a^3}$

mass of "all" formula units inside unit cell:

$= 6.80 \frac{g}{cm^3} (4.77 \times 10^{-8} cm)^3 = 7.38 \times 10^{-22}$ g

② $\frac{111.1 \text{ g } CaCl_2}{1 \text{ mole } CaCl_2} \left(\frac{1 \text{ mole } CaCl_2}{6.02 \times 10^{23} \text{ formula units}} \right)$ no of formula units $= 7.38 \times 10^{-22}$ g

no of formula units:

$= 7.38 \times 10^{-22} g \left(\frac{6.02 \times 10^{23} \text{ formula units}}{1 \text{ mole } CaCl_2} \right) \left(\frac{1 \text{ mole } CaCl_2}{111.1 \text{ g } CaCl_2} \right) = 4$ formula units

3. A metal crystallizes in a cubic closest packing structure and its density is 9.25 g/cm^3. What is the molar mass of the metal, if the volume of its **atom** is 8.23 x 10^{-24} cm^3?

Answer: 61.8 g/mole

i) $V = \frac{4}{3} \pi r^3$

$8.23 \times 10^{-24} cm^3 = \frac{4}{3}(3.4) r^3$

$r = 1.25 \times 10^{-8}$ cm

ii) $a = \frac{4r}{\sqrt{2}} = \frac{4(1.25 \times 10^{-8} cm)}{\sqrt{2}} = 3.54 \times 10^{-8}$ cm

iii) $V_{unit cell} = a^3 = (3.54 \times 10^{-8} cm)^3 = 4.44 \times 10^{-23} cm^3$

iv) mass of unit cell = mass of all atoms $= 9.25 \frac{g}{cm^3} \times 4.44 \times 10^{-23} cm^3 = 41.1 \times 10^{-23}$ g

v) mass of one atom $= \frac{41.1 \times 10^{-23} g}{4 \text{ atoms}} = 1.03 \times 10^{-22}$ g/atom

vi) molar mass $= 1.03 \times 10^{-22}$ g/atom $\left(\frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mole}} \right) = 61.8$ g/mole

4. a. Name the four types of crystalline solids.

i) molecular ii) ionic iii) metallic iv) covalent network

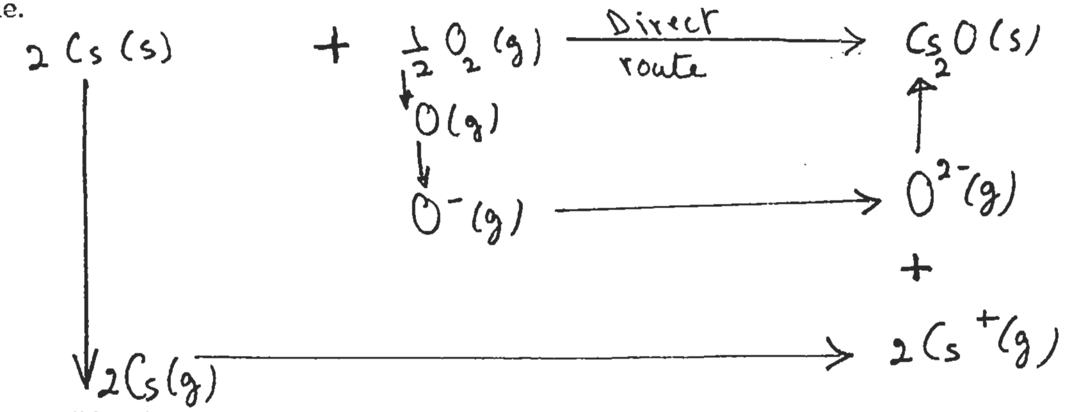
b. Indicate the **type of crystalline solid** each of the following would form upon solidification. Tell what **type of particles** are located at the lattice points and the **types of attractive forces** that exist between the particles.

	Type of crystalline solid	Type of particles at lattice points	Attractive forces
S_8	molecular	molecules	Intermolecular forces
HF	molecular	molecules	Intermolecular forces
potassium permanganate	ionic	cations and anions	electrostatic attraction (ionic bond)
Ni	metallic	cations	attraction between positive ions and mobile sea of electrons.
Si	covalent network	atoms	covalent bond

Set C :

1) a)What is the chemical formula for cesium oxide? Answer Cs_2O.

b) Draw a diagram sketching Born Haber cycle for the formation of cesium oxide.



c) Use the following data to calculate the lattice energy of cesium oxide. You must write all thermochemical equations for the steps of the cycle.

Enthalpy of formation of cesium oxide = - 233 kj/mole

Enthalpy of sublimation of Cs = + 78 kj/mole

First ionization energy of Cs = + 375 kj/mole

Enthalpy of dissociation of O_2 (g) = + 494 kj/mole of O_2 molecules

First electron affinity of O = - 141 kj/mole of O atoms

Second electron affinity of O = + 845 kj/mole of O^- ions Answer : - 2090 kj

$2Cs(s) \longrightarrow 2Cs(g$ $\quad \Delta H = 2\text{moles}\left(+78\frac{kj}{mole}\right) = +156\,kj$

$2Cs(g) \longrightarrow 2Cs^+(g) + 2e^-$ $\quad \Delta H = 2\text{ moles}(375\,kj/mole) + 750\,kj$

$\frac{1}{2}O_2(g) \longrightarrow O(g)$ $\quad \Delta H = 0.5\text{ mole}\left(494\frac{kj}{mole}\right) = +247\,kj$

$O(g) + 1e^- \longrightarrow O^-(g)$ $\quad \Delta H = -141\,kj$

$O^-(g) + 1e^- \longrightarrow O^{2-}(g)$ $\quad \Delta H = +845\,kj$

$2Cs^+(g) + O^{2-}(g) \longrightarrow Cs_2O(s)$ $\quad \Delta H_{lattice} = ?$

Add: $2Cs(s) + \frac{1}{2}O_2(g) \rightarrow Cs_2O(s)$ $\quad \Delta H_{formation} = -233\,kj$

$$\Delta H_{form.} = \Delta H_{sub.} + \Delta H_{ioniz.} + \Delta H_{diss.} + \Delta H_{1st\ I.E.} + \Delta H_{2nd\ I.E} + \Delta H_{lattice}$$

$$-233\,kj = 2(78)\,kj + 2(375)\,kj + \frac{494}{2}\,kj - 141\,kj + 845\,kj + \Delta H_{lattice}$$

$$\Delta H_{lattice} = -2890\,kj$$

2) Nickel has a cubic unit cell. The edge of the unit cell is 3.524×10^{-8} cm. The density of metallic nickel is 8.91 g/cm^3.

a) How many nickel atoms are in the unit cell?

Answer: 4 atoms. face-centered cube

Setup: (1) $V_{unit\ cell} = a^3 = (3.524 \times 10^{-8} cm)^3 = 4.376 \times 10^{-23} cm^3$

(2) mass of unit cell: $4.376 \times 10^{-23} cm^3 \left(\frac{8.91\ g}{cm^3}\right) = 3.90 \times 10^{-22} g$

(3) $3.90 \times 10^{-22} g \left(\frac{1\ mole\ Ni}{58.69 g\ Ni}\right)\left(\frac{6.02 \times 10^{23} atoms\ Ni}{1\ mole\ Ni}\right) =$ 4 atoms

b) Calculate the radius of a nickel atom based on your result of question (a) above.

$\sqrt{2}\ a = 4r$

Answer: b) 1.246×10^{-8} cm

Setup:

$r = \frac{\sqrt{2}\ a}{4} = \frac{\sqrt{2}(3.524 \times 10^{-8} cm)}{4} = 1.246 \times 10^{-8} cm$

3) The volume of a metal atom is 7.24×10^{-24} cm^3. The metal crystallizes in a cubic closest packing structure. The density of the metal is 8.77 g/cm^3. What is the molar mass of the metal?

Answer : 51.5 g/mole

1) $V_{atom} = \frac{4}{3}\pi r^3$

$7.24 \times 10^{-24} cm^3 = \frac{4}{3}(3.14) r^3$

$r = 1.20 \times 10^{-8} cm$

(2) for a face-centered cube: $\sqrt{2}\ a = 4r$

$a = \frac{4r}{\sqrt{2}} = \frac{4(1.20 \times 10^{-8} cm)}{1.414} = 3.39 \times 10^{-8} cm$

(3) volume of a cube $= a^3 = (3.39 \times 10^{-8} cm)^3 = 39.0 \times 10^{-24} cm^3$

(4) mass of the cube = mass of 4 atoms

$= 39.0 \times 10^{-24} cm^3 \left(\frac{8.77 g}{cm^3}\right) = 3.42 \times 10^{-22} g$

(5) mass of one atom $= \frac{3.42 \times 10^{-22} g}{4 atoms} = 8.55 \times 10^{-23} g/atom$

(6) molar mass $= \frac{6.02 \times 10^{23} atoms}{1 mole}\left(\frac{8.55 \times 10^{-23} g}{1 atom}\right) =$ 51.5 g/mole

4) Indicate the **type of crystalline solid** each of the following would form upon solidification.Tell what **type of particles** are located at the lattice points and the **types of attractive forces** that exist between the particles.

	Type of crystalline solid	Type of particle(s) at lattice point	Attractive forces between lattice points
NH_4HSO_4	ionic	Cations and anions	Electrostatic attraction (ionic bond)
SiO_2	covalent network	atoms	covalent
Si	covalent network	atoms	covalent
HCl	molecular	molecules	Intermolecular forces
Al	metallic	cations	(attraction between cations and mobile sea of electrons)
I_2	molecular	molecules	Intermolecular forces

5) Manganese crystallizes in a face-centered cubic system. The radius of the manganese **atom** is 1.30 x 10 $^{-8}$ cm. What is the density of manganese?

Answer: 7.32 g/cm3

(1) $\boxed{\sqrt{2}\ a = 4r}$

$a = \frac{4r}{\sqrt{2}} = \frac{4(1.30 \times 10^{-8} cm)}{1.414} = 3.68 \times 10^{-8} cm$

(2) volume of cube $= a^3 = (3.68 \times 10^{-8} cm)^3 = 4.98 \times 10^{-23} cm^3$

(3) mass of one atom:

$= 54.99 \frac{g}{mole} \left(\frac{1 mole Mn}{6.02 \times 10^{23} atoms} \right) = 9.12 \times 10^{-23} \frac{g}{atom}$

(4) mass of four atoms = mass of cube:

$= 4 \text{ atoms} \left(\frac{9.12 \times 10^{-23} g}{atom} \right) = 3.65 \times 10^{-22} g$ ← mass of cube

(5) $D = \frac{\text{mass of unit cell}}{\text{volume of unit cell}} = \frac{3.65 \times 10^{-22} g}{4.98 \times 10^{-23} g} = 7.32\ g/cm3$

6) Associate each of the solids: CsI, SiO_2, Ni, and $SiCl_3H$ with one of the following sets of properties:

a) A very hard solid subliming at 2900 ° C. SiO_2

b) A yellowish solid having a melting point of 40 ° C and is a nononductor of electricity in the molten state. $SiCl_3H$

c) A lustrous solid melting at about 1600 ° C . Both the solid and the liquid are electrically conductors. Ni

d) A white solid melting at about 700°C. The liquid is electrically conducting although the solid is not. CsI