1. (10 points) Self heating meals such as the one shown in Figure 1 are available.

Figure 1: A self-heating beef hot pot available at T & T supermarket.

Commonly, powdered calcium oxide is contained within a porous pouch and this is placed into a small amount of water. The water and calcium oxide react, producing heat according to the following reaction:

$$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)}$$

If 300 g of liquid water at room temperature is added to 250 g of calcium oxide, determine how many grams of water will remain after the reaction is complete. To simplify your calculations you may neglect the heating of any solids present.

water $25°$ $\xrightarrow{mC\Delta T}$ water $100°$ $\longrightarrow$ vapour $100°$ $(\Delta_{vap}H \cdot n)$ A_{H_2O} → mass evaporated.

liq. H_2O

1) what is enthalpy change of Rx?

$\Delta_R H = \Delta_f H°(Ca(OH)_{2s}) - \Delta_f H°(CaO_{(s)}) - \Delta_f H°(H_2O(l))$

$= -987 + 635 + 285.8 = -66.2$ kJ/mol 1

2) how many mols of CaO in 250 g?

Ca = 40.078 g/mol O = 15.999 → 56.077 g/mol

$\frac{250 \text{ g}}{56.077 \text{ g/mol}} = 4.4582$ mol 1

3) enthalpy available $= -66.2 \text{ kJ/mol} \cdot 4.4582 = -295.13$ kJ 1

4) how many mols H_2O in 300 g?

$\frac{300 \text{ g}}{18 \text{ g/mol}} = 16.\bar{6}$ mol 1

5) water to heat $= 16.\bar{6}$ mol $- 4.4582$ mol $= 12.2$ mol. 1

6) energy to heat 12.2 mol H_2O from 25 - 100°C $nC_p\Delta T$

$= 12.2 \text{ mol} \cdot 75.3 \frac{\text{J}}{\text{mol} \cdot \text{K}} \cdot 75 \text{ K} = 68.947$ kJ 1

7) energy remaining to boil water $= 68.947 - 295.13 = -226.18$ kJ 1

8) mols boiled off $226.18 = 40.7 \cdot n \Rightarrow n = 5.56$ 1

9) mols H_2O remaining $12.2 - 5.56 = 6.6428$ 1

8) mols boiled off $226.18 = 40.7 \cdot n \Rightarrow n = 5.56$ (1)

9) mols H_2O remaining $12.2 - 5.56 = 6.6428$ (1)

10) mass H_2O remaining : $6.6428 \text{ mol} \cdot 18 \frac{g}{mol} = \boxed{120 \text{ g}}$ (1)

2. This question pertains to the iron-carbon phase diagram, shown in Figure 2.

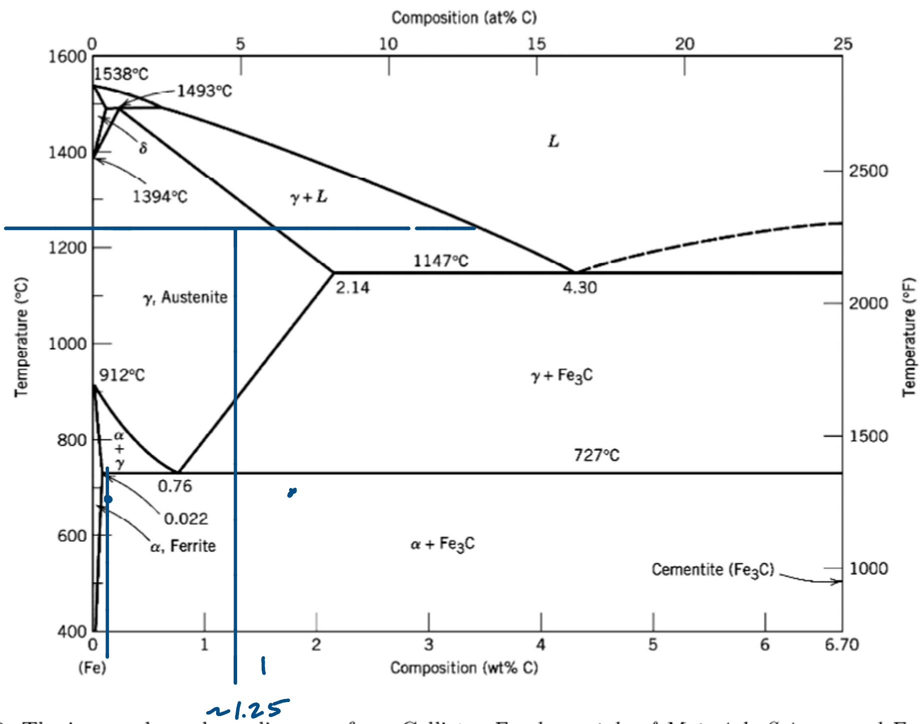


Figure 2: The iron-carbon phase diagram, from Callister *Fundamentals of Materials Science and Engineering*

(a) (2 points) For a 1 kg sample of 0.1 wt%C steel at 728 °C, what will be the mass, in grams, of carbon that is dissolved in iron?

at 728, 0.1 wt% = $\alpha + \gamma$, both solid solution, so $1000\text{g} \cdot 0.001 = \boxed{1 \text{ g}}$ (1)

(b) (2 points) For a 1 kg sample of 0.1 wt%C steel at 726 °C, what will be the mass, in grams, of carbon that is dissolved in iron?

at 726 only dissolved in α (1) $\frac{6.7-0.1}{6.7-0.022} \cdot \frac{0.022}{100} = 2.17(10^{-4})\text{g} = 2 \times 10^{-4}$ g (1)

(c) (2 points) For a 1 kg sample of 1.7 wt%C steel at 728 °C, what will be the mass, in grams, of cementite?

$\frac{1.7-0.76}{6.7-0.76} \cdot 1000\text{g} = 160$ g (2)

(d) (2 points) For a 1 kg sample of 4.3 wt%C cast iron at 1148 °C, what will be the mass, in grams, of liquid?

1000 g (2)

(e) (2 points) For a 1 kg sample of an alloy of this system heated to 1300 °C, what will be the maximum composition that would ensure no liquid is present?

~ 1.25 wt% C (2) (accept ~ 1.1 – 1.4)

3. Match the most appropriate word(s) to each concept described below by writing the number corresponding to the correct word(s) on the line beside each concept.

1. Standard formation enthalpy
2. Standard formation entropy
3. Tetrahedral interstitial site
4. Twelve
5. Endothermic
6. Only lowest energy state occupied
7. Solid solution
8. Exothermic
9. State variable
10. Four
11. BCC
12. Tetrahedral
13. Metallic
14. HCP
15. sp^3 hybridized orbitals
16. Face centred cubic
17. Eight
18. Band gap
19. Material property
20. Only highest state occupied
21. Extensive variable
22. All states equally occupied
23. Path variable
24. Low band gap
25. Simple cubic

① each

(a) (1 point) 14 The crystal structure having only parallel close-packed planes.

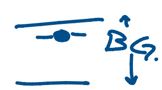
(b) (1 point) 5 The term describing the direction of heat flow in the evaporation of liquid water to gas water.

(c) (1 point) 6 The best description for the theoretical distribution of particles over possible energy states for a substance at the absolute zero of temperature.

(d) (1 point) 10 The coordination number for atoms in the diamond cubic crystal structure.

(e) (1 point) 1 A commonly tabulated thermodynamic quantity expressed in relative terms.

(f) (1 point) 18 Where the donor level is located in an n-type semiconductor.



(g) (1 point) 21 or 9 The volume is this type of thermodynamic variable.

(h) (1 point) 23 The work performed by a system is this type of thermodynamic variable.

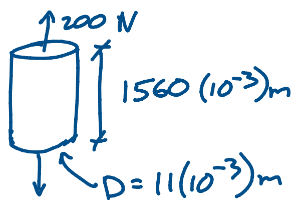
(i) bonus ~~(1 point)~~ SIX option not here! The coordination number of the interstitial site that would be occupied by a cation that was slightly larger than the ideal size for the tetrahedral interstitial site. ① if student noted that correct option not available.

→ octahedral → CN=6

(j) (1 point) 13 The nature of the bonding within crystalline iron.

4. A cylindrical sample of an aluminum alloy has a Young's modulus of 68.0 GPa, a yield strength of 285.0 MPa, an ultimate tensile strength of 365.0 MPa, a fracture strength of 300.0 MPa, initial diameter of 11.0 mm, and initial length of 1560.0 mm. This sample is loaded with 200 N and then unloaded.

(a) (3 points) If possible, determine the length of this sample while loaded. If not possible, explain why not.



$\sigma = \frac{F}{A_0} = \frac{200 \cdot 4}{\pi [11(10^{-3})]^2} = 2.1045\,MPa$ so elastic 1

$l_f = l_0 + \Delta l \qquad \varepsilon = \frac{\Delta l}{l_0} \Rightarrow \Delta l = \varepsilon \cdot l_0$ 1

$\sigma = E \cdot \varepsilon \Rightarrow \varepsilon = \frac{\sigma}{E} \Rightarrow l_f = l_0 + \frac{\sigma}{E} \cdot l_0$ 1

$l_f = 1560(10^{-3}) + \frac{2.1045(10^6)}{68(10^9)} \cdot 1560(10^{-3}) = \boxed{1560\,mm}$

(b) (3 points) What would be the highest load that this sample can support without undergoing non-uniform plastic deformation?

$\sigma_{UTS} = \underbrace{365(10^6)}_{1} = \frac{F}{A_0}$ 1 $\Rightarrow F = 365(10^6) \cdot \frac{\pi \cdot [11(10^{-3})]^2}{4}$

$\boxed{= 35\ kN}$ 1

(c) (1 point) What would be the highest load that this sample can support without undergoing uniform plastic deformation?

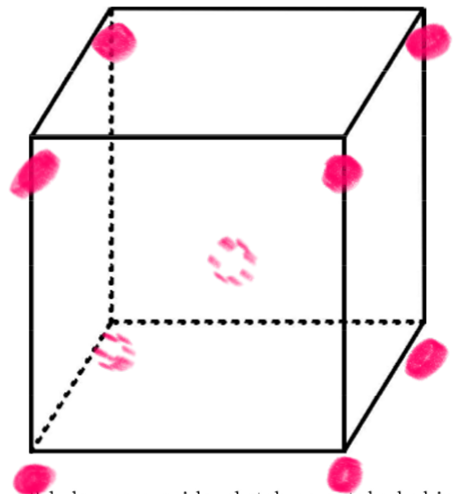
$\sigma_y = 285\,MPa$ 1

$F = 285(10^6) \cdot \frac{\pi [11(10^{-3})]^2}{4} = \boxed{27\,kN}$

1 1

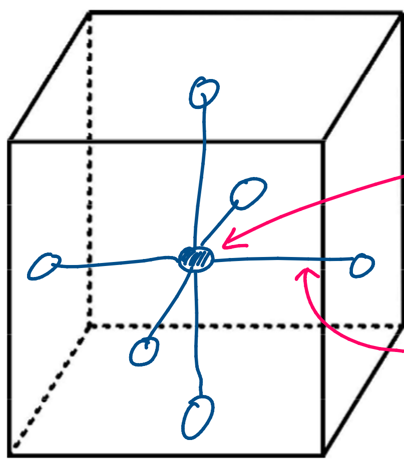
5. This question pertains to crystal structures. For each of the sketches, please use a reduced sphere depiction, rather than a full hard sphere model.

   (a) (2 points) In the unit cell below, sketch the atom positions within the body centred cubic crystal structure.



2

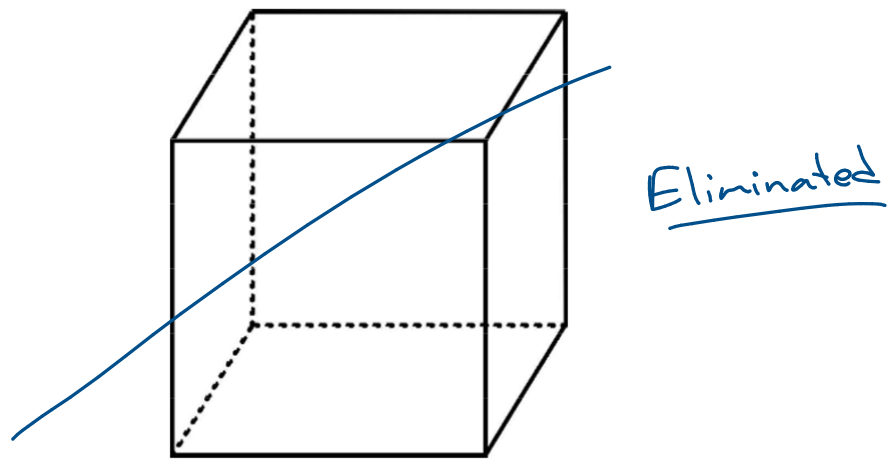
   (b) (2 points) Using the unit cell below as a guide, sketch an octahedral interstitial site centred at the centre of the cube. Include an atom in the interstitial site at the centre of the cube and clearly identify the direction of contact between atoms.



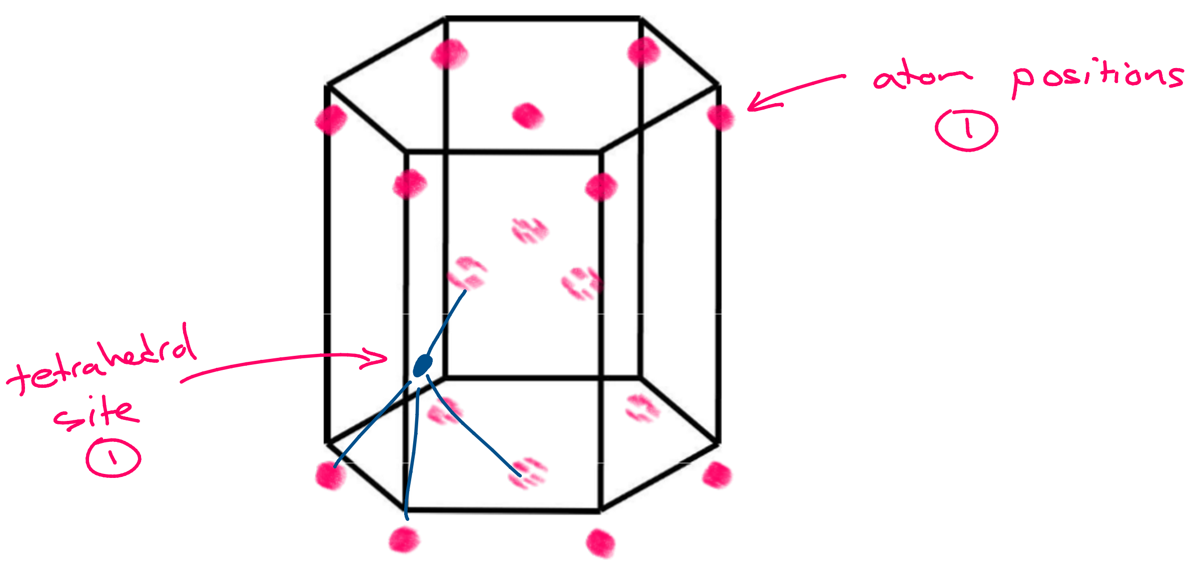
1

direction of contact 1

(c) (2 points) In the unit cell below, sketch the atom positions within the body-centred cubic crystal structure.



(d) (2 points) Using the unit cell below as an aid, indicate the atom positions within the hexagonal close packed crystal structure and then clearly show one tetrahedral interstitial site within the unit cell, clearly indicating direction from the interstitial site to nearest neighbour atoms.



6. A sample of a polymer contains the following fractions of polymer chains with their respective molecular weights:

Fraction of Polymer Chains (w_i)	Molecular Weight (M_i) (g/mol)
0.10	20,000
0.30	50,000
0.40	80,000
0.20	120,000

(a) (2 points) Calculate the number average molecular weight for the polymer sample.

(b) (5 points) Calculate the weight average molecular weight for the polymer sample.

(c) (3 points) Discuss the distribution of molecular weights in this polymer.

a) can't calculate without number fraction of each bin. x_i
but must be greater than $\overline{M}_w$ 2

b) $\overline{M}_w = \sum_{n=1}^{i} M_n w_n = 2(10^4) \cdot 0.1 + 5(10^4)\,0.3 + 8(10^4)\,0.4 + 12(10^4)\,0.2 = 73{,}000$ g/mol 5

c) difficult to say much without x_i data. we could compare the $\overline{M}_w$ to $\overline{M}_n$ using the dispersity.

$Đ = \frac{\overline{M}_w}{\overline{M}_n}$ to give some insight into how tight the distribution is.

Polymers range from somewhere less than 20,000 g/mol to somewhere over 120,000 g/mol

3

a) and c) award marks for anything reasonable and NOT inaccurate.

MCQ: 1b, 2b, 3a, 4b, 5c, 6b, 7b, 8a, 9d, 10a, 11a, 12b, 13a, 14b, 15c