



**UNIVERSITI KUALA LUMPUR**  
**Malaysia France Institute**

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**FINAL EXAMINATION**  
**JULY 2010 SESSION**

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**SUBJECT CODE** : FTB 11102  
**SUBJECT TITLE** : INTRODUCTION TO MATERIAL SCIENCE  
**LEVEL** : BACHELOR  
**TIME / DURATION** : 4.00 pm – 6.00 pm  
( 2 HOURS )  
**DATE** : 20 NOVEMBER 2010

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**INSTRUCTIONS TO CANDIDATES**

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1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. Please write your answers on the answer booklet provided.
4. Answer should be written in blue or black ink except for sketching, graphic and illustration.
5. This question paper consists of FIVE (5) questions. Answer FOUR (4) questions only.
6. Answer all questions in English.

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THERE ARE 4 PAGES OF QUESTIONS, EXCLUDING THIS PAGE.

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**INSTRUCTION: Answer FOUR (4) questions only.**

**Question 1**

- (a) List **THREE (3)** types of basic materials. (3 marks)
- (b) You would like to design an aircraft that can be flown by human power nonstop for a distance of 30km. What types of material properties would you recommend? What materials would be appropriate? (10 marks)
- (c) Suppose an element has a valence of 2 and an atomic number of 27. Based only on the quantum numbers, how many electrons must be present in the 3d energy level? (4 marks)
- (d) Using the abbreviated quantum number notation (s, p, d, f), write the electronic configurations of the following ions: (8 marks)
- (i)  $S^{2-}$  (Atomic number for sulfur = 16)
  - (ii)  $Ba^{2+}$  (Atomic number for barium = 56)
  - (iii)  $Sr^{2+}$  (Atomic number for strontium = 38)
  - (iv) Ge

**Question 2**

- (a) Calculate the volume of face centered cubic (FCC) unit cell in terms of the atomic radius, R. (5 marks)
- (b) Assuming that silica ( $SiO_2$ ) has 100% covalent bonding, describe how oxygen and silicon atoms in silica ( $SiO_2$ ) are joined? (5 marks)

- (c) Indium has a tetragonal unit cell which the 'a' and 'c' lattice parameters are 0.459 and 0.495 nm, respectively.
- (i) If the atomic packing factor and atomic radius are 0.693 and 0.1625 nm, respectively, determine the number of atoms in each unit cell.
  - (ii) The atomic weight of Indium 114.82 g/mol; compute its theoretical density.
- (10 marks)

- (d) Draw within a cubic unit cell the  $(\bar{2}12)$  and  $(0\bar{1}1)$  planes.
- (5 marks)

### Question 3

- (a) Sketch a respective diagram showing self-Interstitial and Frenkel defect.
- (4 marks)
- (b) Calculate the concentration of vacancies in copper at room temperature (25°C). What temperature will be needed to heat treat copper such that the concentration of vacancies produced will be 1000 times more than the equilibrium concentration of vacancies at room temperature? Assume that 20,000 cal are required to produce a mole of vacancies in copper and lattice parameter is 0.36151 nm.
- (10 marks)
- (c) Dislocations are most significant in metals and alloys since they provide a mechanism for plastic deformation. Discuss why would metals behave as brittle materials without dislocations?
- (5 marks)
- (d) There are several types of planar defects. The most important planar defect is grain boundaries. Describe this defect and differentiate these two categories of grain boundaries.
- (6 marks)

### Question 4

- (a) A Copper – Silver (Cu - Ag) phase diagram is shown in the Figure 1. Consider a 48% Ag - 52% Cu alloy.
- i) Name the line that labeled as A,B and C.

(3 marks)

ii) Name point D

(1 marks)

iii) Determine the percentage of the phases at 778°C in  $\alpha + \beta$  phase

(10 marks)

iv) Upon crossing the eutectic isotherm, the liquid transforms to  $\alpha$  and  $\beta$  phases. Give the transformation equation to represent the reaction involved.

(3 marks)

v) Sketch the microstructure in  $\alpha + L$  phase.

(4 marks)

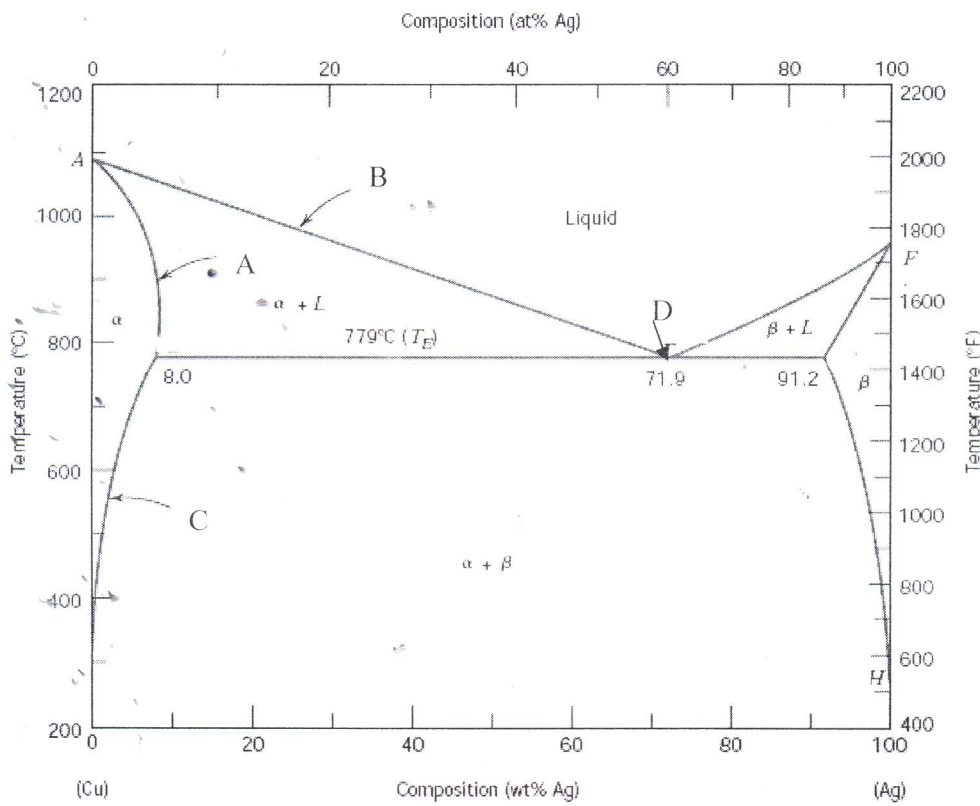


Figure 1: Cu-Ag Phase Diagram

(b) For a bronze alloy, the stress at which plastic deformation begins is 275 MPa, and the modulus of elasticity is 115 GPa.

What is the maximum load that may be applied to a specimen with a cross-sectional area of 225 mm<sup>2</sup> without plastic deformation?

(4 marks)

**Question 5**

(a) Figure 2 shows the tensile engineering stress–strain behavior for a steel alloy.

- i. Define the proportional limit. (3 marks)
- ii. Determine the modulus of elasticity. (3 marks)
- iii. Determine the yield strength at a strain offset of 0.002. (4 marks)

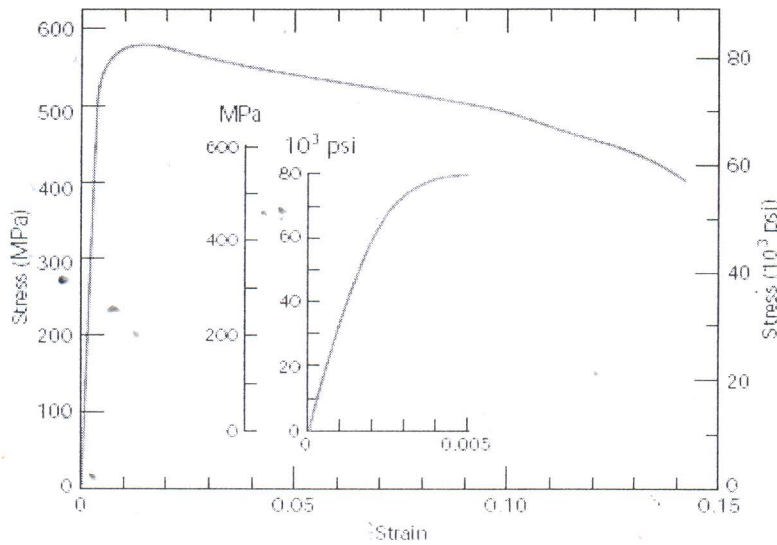


Figure 2: Tensile stress-strain curve for plain carbon steel

(b) A cylindrical specimen of brass having a diameter of 19 mm and length of 200 mm is deformed elastically in tension with a force of 48,800 N. The modulus of elasticity is 69 GPa. Determine the amount of elongation in the direction of the applied stress.

(15 marks)

**END OF QUESTION**



| IA |   | IIA |    | IIIB |   | IVB |    | VB |    | VIB |    | VIIB |   | VIII |    | IIB |    | IIIA |    | IVA |    | VIA |    | VIIA |    | 0  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |     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| 1  | H | 3   | Li | 20   | K | 22  | Ca | 23 | Sc | 24  | Ti | 25   | V | 26   | Cr | 27  | Mn | 28   | Fe | 29  | Co | 30  | Ni | 31   | Cu | 32 | Zn | 33 | Ga | 34 | Ge | 35 | As | 36 | Se | 37 | Br | 38 | Kr | 39 | Rb | 40 | Sr | 41 | Y | 42 | Zr | 43 | Nb | 44 | Mo | 45 | Tc | 46 | Ru | 47 | Rh | 48 | Pd | 49 | Ag | 50 | Cd | 51 | In | 52 | Sn | 53 | Sb | 54 | Te | 55 | I | 56 | Xe | 57 | La | 58 | Ce | 59 | Pr | 60 | Nd | 61 | Pm | 62 | Sm | 63 | Eu | 64 | Gd | 65 | Tb | 66 | Dy | 67 | Ho | 68 | Er | 69 | Tm | 70 | Yb | 71 | Lu | 72 | Ac | 73 | Th | 74 | Pa | 75 | U | 76 | Np | 77 | Pu | 78 | Am | 79 | Cm | 80 | Bk | 81 | Cf | 82 | Es | 83 | Fm | 84 | Md | 85 | Nb | 86 | Lw | 87 | Fr | 88 | Ra | 89 | Ac | 90 | Th | 91 | Pa | 92 | U | 93 | Np | 94 | Pu | 95 | Am | 96 | Cm | 97 | Bk | 98 | Cf | 99 | Es | 100 | Fm | 101 | Md | 102 | Nb | 103 | Lw | 104 | Rn | 105 | At | 106 | Po | 107 | Bi | 108 | Pb | 109 | Tl | 110 | Pb | 111 | Bi | 112 | Po | 113 | At | 114 | Rn | 115 | Fr | 116 | Ra | 117 | Ac | 118 | Th | 119 | Pa | 120 | U | 121 | Np | 122 | Pu | 123 | Am | 124 | Cm | 125 | Bk | 126 | Cf | 127 | Es | 128 | Fm | 129 | Md | 130 | Nb | 131 | Lw | 132 | Rn | 133 | At | 134 | Po | 135 | Bi | 136 | Pb | 137 | Tl | 138 | Pb | 139 | Bi | 140 | Po | 141 | At | 142 | Rn | 143 | Fr | 144 | Ra | 145 | Ac | 146 | Th | 147 | Pa | 148 | U | 149 | Np | 150 | Pu | 151 | Am | 152 | Cm | 153 | Bk | 154 | Cf | 155 | Es | 156 | Fm | 157 | Md | 158 | Nb | 159 | Lw | 160 | Rn | 161 | At | 162 | Po | 163 | Bi | 164 | Pb | 165 | Tl | 166 | Pb | 167 | Bi | 168 | Po | 169 | At | 170 | Rn | 171 | Fr | 172 | Ra | 173 | Ac | 174 | Th | 175 | Pa | 176 | U | 177 | Np | 178 | Pu | 179 | Am | 180 | Cm | 181 | Bk | 182 | Cf | 183 | Es | 184 | Fm | 185 | Md | 186 | Nb | 187 | Lw | 188 | Rn | 189 | At | 190 | Po | 191 | Bi | 192 | Pb | 193 | Tl | 194 | Pb | 195 | Bi | 196 | Po | 197 | At | 198 | Rn | 199 | Fr | 200 | Ra | 201 | Ac | 202 | Th | 203 | Pa | 204 | U | 205 | Np | 206 | Pu | 207 | Am | 208 | Cm | 209 | Bk | 210 | Cf | 211 | Es | 212 | Fm | 213 | Md | 214 | Nb | 215 | Lw | 216 | Rn | 217 | At | 218 | Po | 219 | Bi | 220 | Pb | 221 | Tl | 222 | Pb | 223 | Bi | 224 | Po | 225 | At | 226 | Rn | 227 | Fr | 228 | Ra | 229 | Ac | 230 | Th | 231 | Pa | 232 | U | 233 | Np | 234 | Pu | 235 | Am | 236 | Cm | 237 | Bk | 238 | Cf | 239 | Es | 240 | Fm | 241 | Md | 242 | Nb | 243 | Lw | 244 | Rn | 245 | At | 246 | Po | 247 | Bi | 248 | Pb | 249 | Tl | 250 | Pb | 251 | Bi | 252 | Po | 253 | At | 254 | Rn | 255 | Fr | 256 | Ra | 257 | Ac | 258 | Th | 259 | Pa | 260 | U | 261 | Np | 262 | Pu | 263 | Am | 264 | Cm | 265 | Bk | 266 | Cf | 267 | Es | 268 | Fm | 269 | Md | 270 | Nb | 271 | Lw | 272 | Rn | 273 | At | 274 | Po | 275 | Bi | 276 | Pb | 277 | Tl | 278 | Pb | 279 | Bi | 280 | Po | 281 | At | 282 | Rn | 283 | Fr | 284 | Ra | 285 | Ac | 286 | Th | 287 | Pa | 288 | U | 289 | Np | 290 | Pu | 291 | Am | 292 | Cm | 293 | Bk | 294 | Cf | 295 | Es | 296 | Fm | 297 | Md | 298 | Nb | 299 | Lw | 300 | Rn | 301 | At | 302 | Po | 303 | Bi | 304 | Pb | 305 | Tl | 306 | Pb | 307 | Bi | 308 | Po | 309 | At | 310 | Rn | 311 | Fr | 312 | Ra | 313 | Ac | 314 | Th | 315 | Pa | 316 | U | 317 | Np | 318 | Pu | 319 | Am | 320 | Cm | 321 | Bk | 322 | Cf | 323 | Es | 324 | Fm | 325 | Md | 326 | Nb | 327 | Lw | 328 | Rn | 329 | At | 330 | Po | 331 | Bi | 332 | Pb | 333 | Tl | 334 | Pb | 335 | Bi | 336 | Po | 337 | At | 338 | Rn | 339 | Fr | 340 | Ra | 341 | Ac | 342 | Th | 343 | Pa | 344 | U | 345 | Np | 346 | Pu | 347 | Am | 348 | Cm | 349 | Bk | 350 | Cf | 351 | Es | 352 | Fm | 353 | Md | 354 | Nb | 355 | Lw | 356 | Rn | 357 | At | 358 | Po | 359 | Bi | 360 | Pb | 361 | Tl | 362 | Pb | 363 | Bi | 364 | Po | 365 | At | 366 | Rn | 367 | Fr | 368 | Ra | 369 | Ac | 370 | Th | 371 | Pa | 372 | U | 373 | Np | 374 | Pu | 375 | Am | 376 | Cm | 377 | Bk | 378 | Cf | 379 | Es | 380 | Fm | 381 | Md | 382 | Nb | 383 | Lw | 384 | Rn | 385 | At | 386 | Po | 387 | Bi | 388 | Pb | 389 | Tl | 390 | Pb | 391 | Bi | 392 | Po | 393 | At | 394 | Rn | 395 | Fr | 396 | Ra | 397 | Ac | 398 | Th | 399 | Pa | 400 | U | 401 | Np | 402 | Pu | 403 | Am | 404 | Cm | 405 | Bk | 406 | Cf | 407 | Es | 408 | Fm | 409 | Md | 410 | Nb | 411 | Lw | 412 | Rn | 413 | At | 414 | Po | 415 | Bi | 416 | Pb | 417 | Tl | 418 | Pb | 419 | Bi | 420 | Po | 421 | At | 422 | Rn | 423 | Fr | 424 | Ra | 425 | Ac | 426 | Th | 427 | Pa | 428 | U | 429 | Np | 430 | Pu | 431 | Am | 432 | Cm | 433 | Bk | 434 | Cf | 435 | Es | 436 | Fm | 437 | Md | 438 | Nb | 439 | Lw | 440 | Rn | 441 | At | 442 | Po | 443 | Bi | 444 | Pb | 445 | Tl | 446 | Pb | 447 | Bi | 448 | Po | 449 | At | 450 | Rn | 451 | Fr | 452 | Ra | 453 | Ac | 454 | Th | 455 | Pa | 456 | U | 457 | Np | 458 | Pu | 459 | Am | 460 | Cm | 461 | Bk | 462 | Cf | 463 | Es | 464 | Fm | 465 | Md | 466 | Nb | 467 | Lw | 468 | Rn | 469 | At | 470 | Po | 471 | Bi | 472 | Pb | 473 | Tl | 474 | Pb | 475 | Bi | 476 | Po | 477 | At | 478 | Rn | 479 | Fr | 480 | Ra | 481 | Ac | 482 | Th | 483 | Pa | 484 | U | 485 | Np | 486 | Pu | 487 | Am | 488 | Cm | 489 | Bk | 490 | Cf | 491 | Es | 492 | Fm | 493 | Md | 494 | Nb | 495 | Lw | 496 | Rn | 497 | At | 498 | Po | 499 | Bi | 500 | Pb | 501 | Tl | 502 | Pb | 503 | Bi | 504 | Po | 505 | At | 506 | Rn | 507 | Fr | 508 | Ra | 509 | Ac | 510 | Th | 511 | Pa | 512 | U | 513 | Np | 514 | Pu | 515 | Am | 516 | Cm | 517 | Bk | 518 | Cf | 519 | Es | 520 | Fm | 521 | Md | 522 | Nb | 523 | Lw | 524 | Rn | 525 | At | 526 | Po | 527 | Bi | 528 | Pb | 529 | Tl | 530 | Pb | 531 | Bi | 532 | Po | 533 | At | 534 | Rn | 535 | Fr | 536 | Ra | 537 | Ac | 538 | Th | 539 | Pa | 540 | U | 541 | Np | 542 | Pu | 543 | Am | 544 | Cm | 545 | Bk | 546 | Cf | 547 | Es | 548 | Fm | 549 | Md | 550 | Nb | 551 | Lw | 552 | Rn | 553 | At | 554 | Po | 555 | Bi | 556 | Pb | 557 | Tl | 558 | Pb | 559 | Bi | 560 | Po | 561 | At | 562 | Rn | 563 | Fr | 564 | Ra | 565 | Ac | 566 | Th | 567 | Pa | 568 | U | 569 | Np | 570 | Pu | 571 | Am | 572 | Cm | 573 | Bk | 574 | Cf | 575 | Es | 576 | Fm | 577 | Md | 578 | Nb | 579 | Lw | 580 | Rn | 581 | At | 582 | Po | 583 | Bi | 584 | Pb | 585 | Tl | 586 | Pb | 587 | Bi | 588 | Po | 589 | At | 590 | Rn | 591 | Fr | 592 | Ra | 593 | Ac | 594 | Th | 595 | Pa | 596 | U | 597 | Np | 598 | Pu | 599 | Am | 600 | Cm | 601 | Bk | 602 | Cf | 603 | Es | 604 | Fm | 605 | Md | 606 | Nb | 607 | Lw | 608 | Rn | 609 | At | 610 | Po | 611 | Bi | 612 | Pb | 613 | Tl | 614 | Pb | 615 | Bi | 616 | Po | 617 | At | 618 | Rn | 619 | Fr | 620 | Ra | 621 | Ac | 622 | Th | 623 | Pa | 624 | U | 625 | Np | 626 | Pu | 627 | Am | 628 | Cm | 629 | Bk | 630 | Cf | 631 | Es | 632 | Fm | 633 | Md | 634 | Nb | 635 | Lw | 636 | Rn | 637 | At | 638 | Po | 639 | Bi | 640 | Pb | 641 | Tl | 642 | Pb | 643 | Bi | 644 | Po | 645 | At | 646 | Rn | 647 | Fr | 648 | Ra | 649 | Ac | 650 | Th | 651 | Pa | 652 | U | 653 | Np | 654 | Pu | 655 | Am | 656 | Cm | 657 | Bk | 658 | Cf | 659 | Es | 660 | Fm | 661 | Md | 662 | Nb | 663 | Lw | 664 | Rn | 665 | At | 666 | Po | 667 | Bi | 668 | Pb | 669 | Tl | 670 | Pb | 671 | Bi | 672 | Po | 673 | At | 674 | Rn | 675 | Fr | 676 | Ra | 677 | Ac | 678 | Th | 679 | Pa | 680 | U | 681 | Np | 682 | Pu | 683 | Am | 684 | Cm | 685 | Bk | 686 | Cf | 687 | Es | 688 | Fm | 689 | Md | 690 | Nb | 691 | Lw | 692 | Rn | 693 | At | 694 | Po | 695 | Bi | 696 | Pb | 697 | Tl | 698 | Pb | 699 | Bi | 700 | Po | 701 | At | 702 | Rn | 703 | Fr | 704 | Ra | 705 | Ac | 706 | Th | 707 | Pa | 708 | U | 709 | Np | 710 | Pu | 711 | Am | 712 | Cm | 713 | Bk | 714 | Cf | 715 | Es | 716 | Fm | 717 | Md | 718 | Nb | 719 | Lw | 720 | Rn | 721 | At | 722 | Po | 723 | Bi | 724 | Pb | 725 | Tl | 726 | Pb | 727 | Bi | 728 | Po | 729 | At | 730 | Rn | 731 | Fr | 732 | Ra | 733 | Ac | 734 | Th | 735 | Pa | 736 | U | 737 | Np | 738 | Pu | 739 | Am | 740 | Cm | 741 | Bk | 742 | Cf | 743 | Es | 744 | Fm | 745 | Md | 746 | Nb | 747 | Lw | 748 | Rn | 749 | At | 750 | Po | 751 | Bi | 752 | Pb | 753 | Tl | 754 | Pb | 755 | Bi | 756 | Po | 757 | At | 758 | Rn | 759 | Fr | 760 | Ra | 761 | Ac | 762 | Th | 763 | Pa | 764 | U | 765 | Np | 766 | Pu | 767 | Am | 768 | Cm | 769 | Bk | 770 | Cf | 771 | Es | 772 | Fm | 773 | Md | 774 | Nb | 775 | Lw | 776 | Rn | 777 | At | 778 | Po | 779 | Bi | 780 | Pb | 781 | Tl | 782 | Pb | 783 | Bi | 784 | Po | 785 | At | 786 | Rn | 787 | Fr | 788 | Ra | 789 | Ac | 790 | Th | 791 | Pa | 792 | U | 793 | Np | 794 | Pu | 795 | Am | 796 | Cm | 797 | Bk | 798 | Cf | 799 | Es | 800 | Fm | 801 | Md | 802 | Nb | 803 | Lw | 804 | Rn | 805 | At | 806 | Po | 807 | Bi | 808 | Pb | 809 | Tl | 810 | Pb | 811 | Bi | 812 | Po | 813 | At | 814 | Rn | 815 | Fr | 816 | Ra | 817 | Ac | 818 | Th | 819 | Pa | 820 | U | 821 | Np | 822 | Pu | 823 | Am | 824 | Cm | 825 | Bk | 826 | Cf | 827 | Es | 828 | Fm | 829 | Md | 830 | Nb |

$$APF = (n) \left( \frac{4\pi r^3}{3} \right) \left( \frac{1}{a^3} \right)$$

$$\rho = \frac{nA}{V_c N_A}$$

$$N = \frac{N_A \rho}{A}$$

$$N_v = N \exp\left(\frac{-Q}{kT}\right)$$

$$a_{fcc} = \frac{4r}{\sqrt{2}}$$

$$a_{bcc} = \frac{4r}{\sqrt{3}}$$

$$a_{sc} = 2r$$

$$D = D_o \exp\left(\frac{-Q_d}{RT}\right)$$

$$m_\alpha \text{ phase} = \frac{m_\beta - m_x}{m_\beta - m_\alpha} \times \text{Total Mass}$$

$$m_\beta \text{ phase} = \frac{m_x - m_\alpha}{m_\beta - m_\alpha} \times \text{Total Mass}$$

$$m_L \text{ phase} \% = \frac{m_s \% - m_x \%}{m_s \% - m_L \%} \times 100$$

$$m_s \text{ phase} \% = \frac{m_x \% - m_L \%}{m_s \% - m_L \%} \times 100$$

$$\rho_\alpha = \frac{100}{\frac{C_{A(\alpha)}}{\rho_A} + \frac{C_{B(\alpha)}}{\rho_B}}$$

$$\rho_\beta = \frac{100}{\frac{C_{A(\beta)}}{\rho_A} + \frac{C_{B(\beta)}}{\rho_B}}$$

$$V_\alpha = \frac{\frac{m_\alpha}{\rho_\alpha}}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}}$$

$$V_\beta = \frac{\frac{m_\beta}{\rho_\beta}}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}}$$

$$\sigma = \frac{F}{A_o}$$

$$\varepsilon = \frac{\Delta l}{l_o}$$

$$E = \frac{\sigma}{\varepsilon}$$

$$\% \text{ elongation} = \frac{\Delta l}{l_o} \times 100\%$$

$$\% \text{ area reduction} = \frac{\Delta A}{A_o} \times 100\%$$

$$BHN = \frac{F}{\frac{\pi D}{2} (D - \sqrt{D^2 - d^2})}$$

$$VHN = \frac{1.85F}{d^2}$$

$$n_{\text{copper}} = 4 \text{ atoms/unit cell}$$

$$k = 1.987 \text{ cal/mol-K}$$

$$APF = (n) \left( \frac{4\pi r^3}{3} \right) \left( \frac{1}{a^3} \right)$$

$$\rho = \frac{nA}{V_c N_A}$$

$$N = \frac{N_A \rho}{A}$$

$$N_v = N \exp\left(\frac{-Q}{kT}\right)$$

$$a_{fcc} = \frac{4r}{\sqrt{2}}$$

$$a_{bcc} = \frac{4r}{\sqrt{3}}$$

$$a_{sc} = 2r$$

$$D = D_o \exp\left(\frac{-Q_d}{RT}\right)$$

$$m_\alpha \text{ phase} = \frac{m_\beta - m_x}{m_\beta - m_\alpha} \times \text{Total Mass}$$

$$m_\beta \text{ phase} = \frac{m_x - m_\alpha}{m_\beta - m_\alpha} \times \text{Total Mass}$$

$$m_L \text{ phase} \% = \frac{m_s \% - m_x \%}{m_s \% - m_L \%} \times 100$$

$$m_s \text{ phase} \% = \frac{m_x \% - m_L \%}{m_s \% - m_L \%} \times 100$$

$$\rho_\alpha = \frac{100}{\frac{C_{A(\alpha)}}{\rho_A} + \frac{C_{B(\alpha)}}{\rho_B}}$$

$$\rho_\beta = \frac{100}{\frac{C_{A(\beta)}}{\rho_A} + \frac{C_{B(\beta)}}{\rho_B}}$$

$$V_\alpha = \frac{\frac{m_\alpha}{\rho_\alpha}}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}}$$

$$V_\beta = \frac{\frac{m_\beta}{\rho_\beta}}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}}$$

$$\sigma = \frac{F}{A_o}$$

$$\varepsilon = \frac{\Delta l}{l_o}$$

$$E = \frac{\sigma}{\varepsilon}$$

$$\% \text{ elongation} = \frac{\Delta l}{l_o} \times 100\%$$

$$\% \text{ area reduction} = \frac{\Delta A}{A_o} \times 100\%$$

$$BHN = \frac{F}{\frac{\pi D}{2} (D - \sqrt{D^2 - d^2})}$$

$$VHN = \frac{1.85F}{d^2}$$



$$APF = (n) \left( \frac{4\pi r^3}{3} \right) \left( \frac{1}{a^3} \right)$$

$$\rho = \frac{nA}{V_c N_A}$$

$$N = \frac{N_A \rho}{A}$$

$$N_v = N \exp\left(\frac{-Q}{kT}\right)$$

$$a_{fcc} = \frac{4r}{\sqrt{2}}$$

$$a_{bcc} = \frac{4r}{\sqrt{3}}$$

$$a_{sc} = 2r$$

$$D = D_o \exp\left(\frac{-Q_d}{RT}\right)$$

$$m_\alpha \text{ phase} = \frac{m_\beta - m_x}{m_\beta - m_\alpha} \times \text{Total Mass}$$

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$$m_L \text{ phase} \% = \frac{m_s \% - m_x \%}{m_s \% - m_L \%} \times 100$$

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$$\rho_\alpha = \frac{100}{\frac{C_{A(\alpha)}}{\rho_A} + \frac{C_{B(\alpha)}}{\rho_B}}$$

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$$V_\alpha = \frac{\frac{m_\alpha}{\rho_\alpha}}{\frac{m_\alpha}{\rho_\alpha} + \frac{m_\beta}{\rho_\beta}}$$

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$$\sigma = \frac{F}{A_o}$$

$$\varepsilon = \frac{\Delta l}{l_o}$$

$$E = \frac{\sigma}{\varepsilon}$$

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