Please mark X to indicate your tutorial section.
Failure to do so will result in a deduction of 5 marks.

TUT 01	
TUT 02	
TUT 03	
TUT 04	
TUT 05	
TUT 06	
TUT 07	
TUT 08	
TUT 09	
TUT 10	
TUT 11	
TUT 12	

UNIVERSITY OF TORONTO

FACULTY OF APPLIED SCIENCE AND ENGINEERING

TERM TEST 1

10 FEBRUARY 2015

First Year

APS 104S

INTRODUCTION TO MATERIALS AND CHEMISTRY

Exam Type B

Examiners: G. Azimi, C Chin, T. Mirkovic, J. Nogami

Q1	/20
Q2	/20
Q3	/20
Q4	/20
Q5	/20
Total	/100

NAME: _____
Last First

STUDENT NO:_____

INSTRUCTIONS:

- This is a Type B examination. Only non-programmable calculators are allowed.
- Answer all 5 questions.
- All work is to be done on the pages of this booklet.
- When answering the questions **include all the steps** of your work on these pages and then **fill the answer in** the respective **boxes**. For additional space, you may use the back of the preceding page.
- Do not unstaple this exam booklet.
- A Formula Sheet and the periodic table are attached to the end of this exam booklet; if you wish, you may tear-off these sheets *only*.
- Exam papers filled out in pencil **will not be eligible for regrading**.

Name: _____ Student No: _____

QUESTION 1: Atomic Bonding and Crystal Structure (20 pts)

(a) Write out the electron configuration for the following elements:[4 pts]

Boron: [1pt]

Potassium: [1pt]

Chromium: [2pt]

(b) The potential energy between Mg^{2+} and O^{2-} ions in a MgO crystal (NaCl crystal structure) can be estimated as

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

where A = 1.61 x 10^{-27} J m, $B = 3.87 \times 10^{-96}$ J m^8, r is the separation (between ion centers) in m, and E is the potential energy in J.

(i) Calculate the equilibrium separation between the ion centers. [5 pts]

(ii) Calculate the bonding energy between the Mg and O ions at this equilibrium distance. [2 pts]

(iii) If the ionic radius of Mg^{2+} is 0.072 nm, what is the ionic radius of O^{2-} ? [2 pts]

(iv) What is the lattice constant for MgO? [2 pts]

(c) Each of the words or phases on the right is associated with one of the four types of bonding. Choose the most appropriate bonding type for each, and put the corresponding letter in the box. [5 pts]

A) Ionic

B) Covalent

C) Metallic

D) van del Waals

☐ silicon

☐ CsCl

☐ Solid Argon

☐ free electrons

☐ nitrogen molecule

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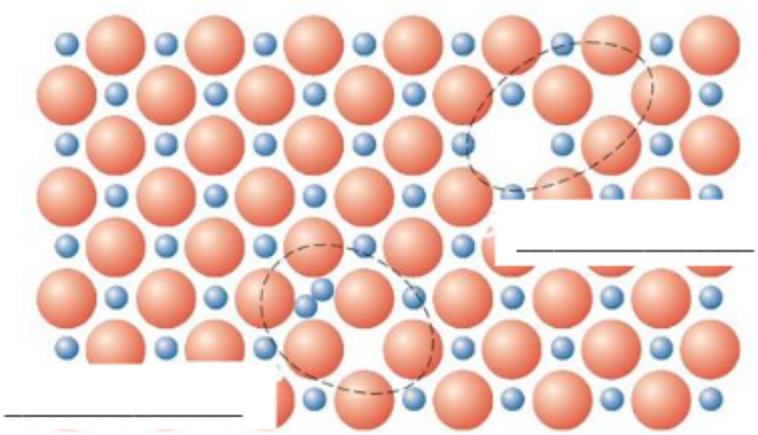
QUESTION 2: Crystal Structure and Defects (20 pts)

(a) Name the two defects in the ionic solid shown below [2 pts]



(b) What is the atomic density of copper, in atoms per cm^3? [2 pts]
Note: the density of Cu is 8.4 g/cm^3

(c) Given that copper is FCC, what is the lattice constant? [4 pts]

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(d) Given the the density of vacancies in a metal is given by:

$N_v = Ne^{-Q/kT}$ where N is the density of Cu atoms per cm^3, and Q = 0.9 eV is the activation energy for vacancy formation.

What is the density of vacancies in Cu at 1000°C? [4 pts]

(e) At what temperature is one out of 10^4 Cu atomic sites a vacancy? [4 pts]

(f) **True / False, one point for each answer** **[4 pts total]**

Check one T	F	
☐	☐	The tensile strength of an alloy is generally lower than that of either of the constituent pure elements.
☐	☐	The yield strength of a polycrystalline metal increases with increasing grain size.
☐	☐	For a screw dislocation, the Burgers vector is parallel to the dislocation line.
☐	☐	In the zincblende crystal structure, the coordination number of the cation and the anion are not the same.

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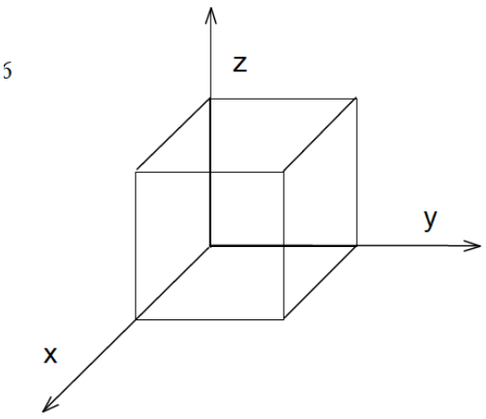
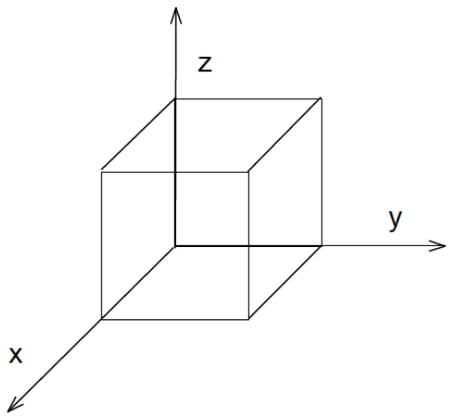
QUESTION 3: Directions, Planes and Densities (20 pts)

a) In the cubic unit cell below sketch the $[10\bar{3}]$plane. [2 pts]

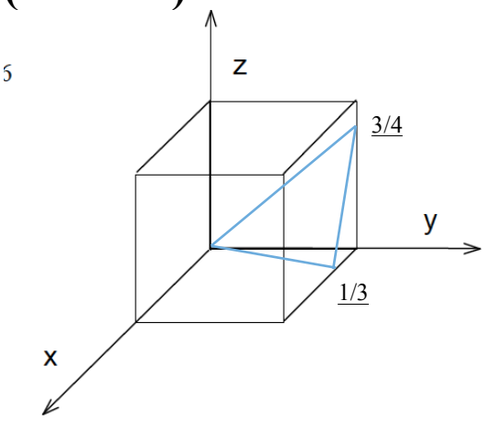


b) In the cubic unit cell below sketch the $(10\bar{3})$ direction. [2 pts]



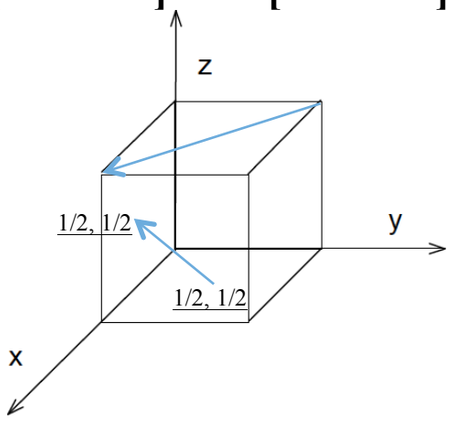
c) In the cubic unit indicate the Miller indices of the plane shown. [2 pts]

( )



d) In the cubic unit cell below, specify the two directions marked. [4 pts]

[ ] [ ]



Iron has a BCC crystal structure with a lattice parameter of 0.407 nm. For this unit cell:

e) Indicate the slip system for the iron crystal structure. [2 pts]

f) Calculate the planar density of the slip plane, in atoms per nm^2 [4 pts]

g) The linear density of atoms along the slip direction, in atoms per nm. [4 pts]

Name: _____ Student No: _____

QUESTION 4: Mechanical properties of materials (20 pts)

The stress strain profile of an isotropic material (Material A) with a diameter of 5.0 mm is shown in Figure 1. The Poisson's ratio is 0.35.

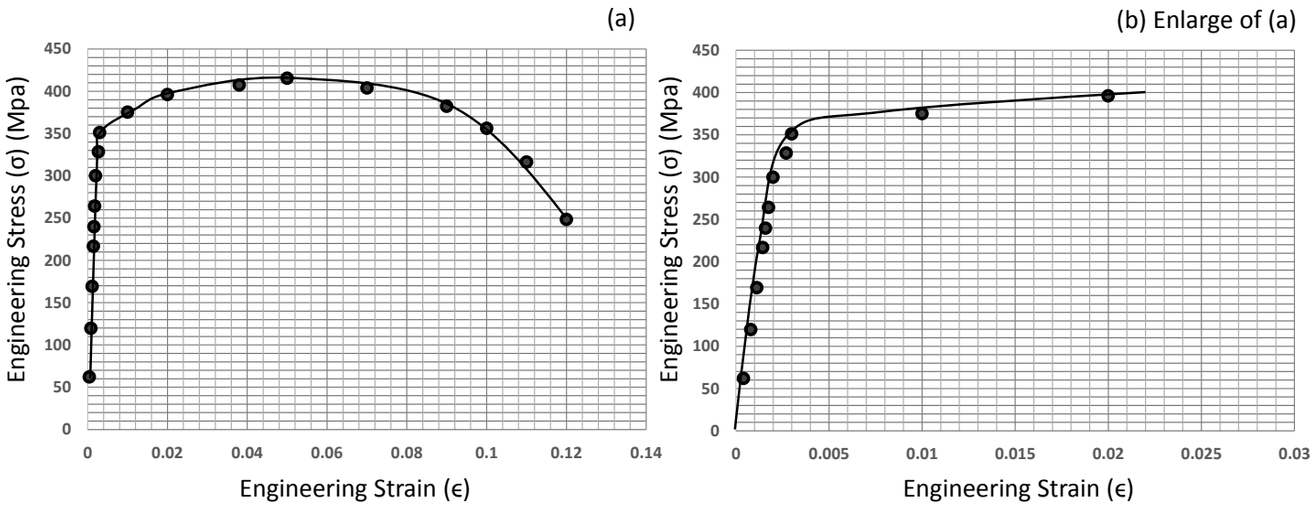


Figure 1. (a) Stress-strain profile for Material A, (b) enlarged plot of the lower strain region of (a).

4a. What is the Young's Modulus of this material? [4 pts]

4b. Under a constant load, the cylinder diameter increases by 2×10^{-3} mm. The deformation is elastic.

The stress is (circle the correct answer): [2 pts]

Tensile Compressive Sheer Torsion

4c. Determine the load for question 4b: [4 pts]

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4d. Show on Figure 1b how you would determine the 0.2 % offset yield strength. The 0.2% offset yield strength is_____. Show your answer on Figure 1b and fill in the box below to receive full credit. [2pts]

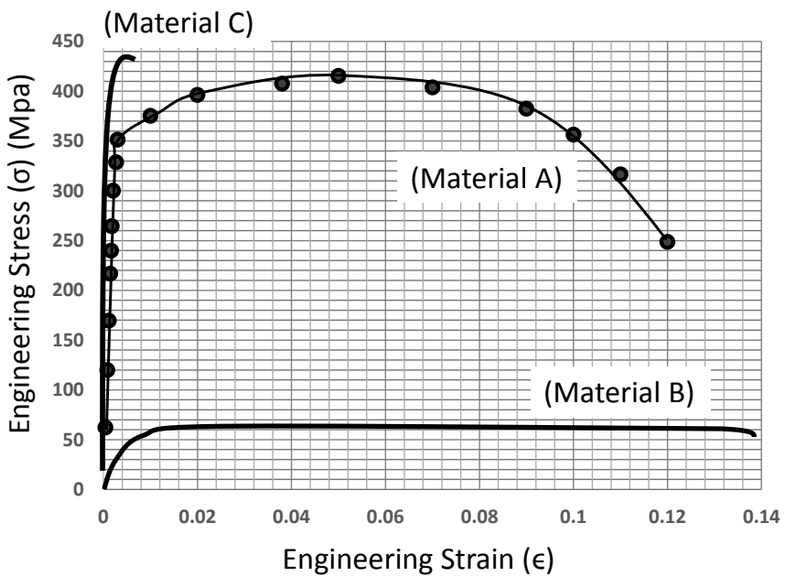

Figure 2. (a) Stress-strain profile for Materials A, B, and C.

Questions 4e-g all refer to Figure 2.

4e) Classify the following Materials as corresponding to curves A, B, C. (circle one) [2 pts each]

Ceramic (Ionic Material) A B C

Polymer A B C

4f) Circle the correct answer: [2 pts]

Material A B C has the highest ductility

4g) Circle the correct answer: [2 pts]

Material A B C has the highest toughness

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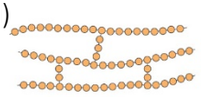
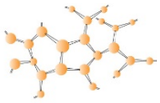
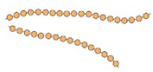
QUESTION 5: Polymers (20 pts)

(a) Draw the monomer and the polymer structure of polyethylene, and polypropylene. [**4 pts**]

(b) The number-average molecular weight of a polypropylene is 1,500,000 g/mol, and an $\overline{M_w}$ = 1,700,000. Compute the degree of polymerization and the polydispersity index for this sample. [**4 pts**]

(c) Describe the polymer sample that has a polydispersity index of 1. [**1 pts**]

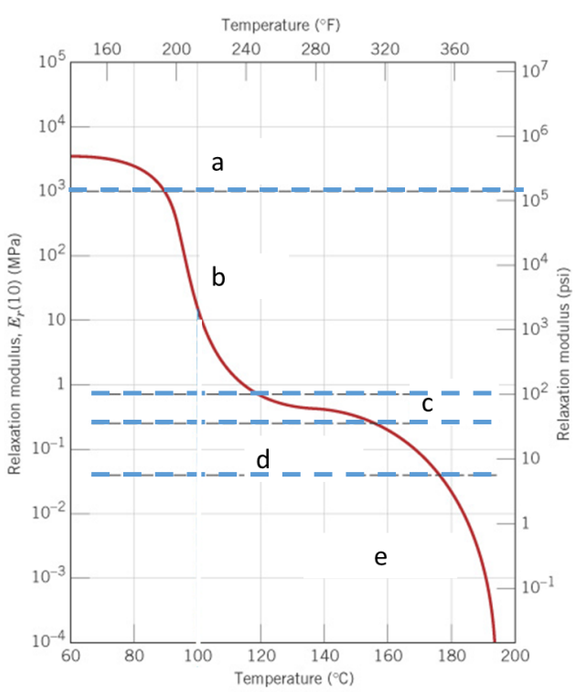
(d) Name the different structures of polymeric chains shown below. [**2 pts**]

	i) 	ii) 	iii) 	iv) 
Name				

(e) The mechanical properties of polymers are known to be temperature-dependant. Determine if the following parameters will increase, decrease, or remain the same as the temperature is increased. [**3 pts**]

Property	Change
Modulus of elasticity	
Tensile strength	
Percent elongation	

(f) The graph below shows the logarithm of the relaxation modulus versus temperature of an amorphous polymer. Name the five regions of viscoelastic behaviour and determine the glass transition temperature (T_g) from the graph. [**6 pts**]



(a)_____

(b)_____

(c)_____

(d)_____

(e)_____

T_g = _____

Name: _____ Student No: _____

FORMULAE & CONSTANTS (You may tear this sheet off.)

Constants

R = 8.3145 J·K^{-1} mol^{-1} = 0.0820574587 L·atm· K^{-1} mol^{-1} = 0.083145 L·bar·K^{-1}·mol^{-1}

1 atm = 101.325 kPa = 1.01325 bar = 14.696 psi = 760 Torr = 760 mmHg

N_A = 6.022 x 10^{23} mol^{-1} k = 8.62 x 10^{-5} eV/K 1 eV = 1.60 x 10^{-19} J

T(K) = T(^{o}C) + 273.15 K;

STP: 273.15K, 1 bar ***SATP***: 298.15K, 1 bar

Formulae from Callister

$V = \frac{4\pi r^3}{3}$ $\rho = \frac{m}{V}$ $\rho = \frac{nA}{V_C N_A}$ $\rho = \frac{n'(\Sigma A_C + \Sigma A_A)}{V_C N_A}$ $\%IC = \{1 - \exp[-0.25(X_A - X_B)^2]\} \times 100$

$E = \int F\, dr$ $\frac{d}{dx}(x^n) = nx^{n-1}$

$$APF = \frac{TotalSphereVolume}{TotalUnitCellVolume} \qquad LD = \frac{NumberOfAtomsCentredOnDirectionVector}{LengthOfDirectionVector}$$

$$PD = \frac{NumberOfAtomsCentredOnAPlane}{AreaOfPlane} \qquad DP = \frac{\overline{M_n}}{m} \qquad \overline{M_n} = \sum x_i M_i \qquad \overline{M_w} = \sum w_i M_i$$

Polydispersity Index = $\overline{M_w} / \overline{M_n}$

$N_V = N \exp(-\frac{Q_v}{kT})$ $N_S = N \exp(-\frac{Q_S}{2kT})$ $N_{fr} = N \exp(-\frac{Q_{fr}}{2kT})$

$E = \frac{\sigma}{\varepsilon}$ $\sigma = \frac{F}{A}$ $\in = \frac{\Delta l}{l}$ $\tau = \frac{F}{A}$ $\tau = G\gamma$ $U_r = \frac{1}{2}\sigma_Y \varepsilon_Y$ $\%CW = \left(\frac{A_0 - A_d}{A_0}\right) \times 100$ G = E/(2(1 +ν))

$\sigma_y = \sigma_o + k_y d^{-1/2}$ $\nu = -\frac{\epsilon_x}{\epsilon_z} = -\frac{\epsilon_y}{\epsilon_z}$ $\tau_R = \sigma \cos\phi \cos\lambda$ $\sigma_y = \frac{\tau_{crss}}{(\cos\phi \cos\lambda)_{max}}$ $V = IR$ $\rho = \frac{RA}{l}$

$\sigma = \frac{1}{\rho}$ $J = \sigma E$ $E = \frac{V}{l}$ $v_d = \mu_e E$ $\sigma = n|e|\mu_e$ $\theta = \cos^{-1}\left(\frac{u_1 u_2 + v_1 v_2 + w_1 w_2}{\sqrt{(u_1^2 + v_1^2 + w_1^2)(u_2^2 + v_2^2 + w_2^2)}}\right)$

Name: _____
You may tear this sheet off.

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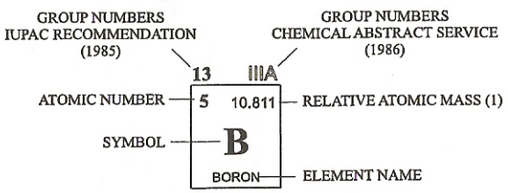
PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/



PERIOD	GROUP 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 H HYDROGEN																	2 4.0026 He HELIUM
2	3 6.941 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.086 Si SILICON	15 30.974 P PHOSPHORUS	16 32.065 S SULPHUR	17 35.453 Cl CHLORINE	18 39.948 Ar ARGON
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.39 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SELENIUM	35 79.904 Br BROMINE	36 83.80 Kr KRYPTON
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.94 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (261) Rf RUTHERFORDIUM	105 (262) Db DUBNIUM	106 (266) Sg SEABORGIUM	107 (264) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (268) Mt MEITNERIUM	110 (281) Uun UNUNNILIUM	111 (272) Uuu UNUNUNIUM	112 (285) Uub UNUNBIUM		114 (289) Uuq UNUNQUADIUM				

LANTHANIDE 6	57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.04 Yb YTTERBIUM	71 174.97 Lu LUTETIUM
ACTINIDE 7	89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)

Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

Editor: Aditya Vardhan (adivar@nettlinx.com)