2017 Battle Of Valley Forge

Material Science Exam

School Name: ____________________ Team Number: _____

Participant 1: ____________________

Participant 2: ____________________

This exam is organized into three parts.

I.	Mechanical Properties of Materials	30 pts
II.	Polymers	30 pts
III.	Crystal Structures	30 pts

- Each part is worth the same amount of points. You may complete them in any order.
- Ties will be won by the team with the highest score on a single part of the exam.
- If at any time you have questions during the exam, please raise your hand immediately.

Part I: Mechanical Properties of Materials

A. Creep Testing

An engineer performs a creep test by subjecting a 2.00m strand of copper wire to a constant load (L) at T=350°C over a period of 132 hours until failure. Strain vs. time data was as follows.

Time (hrs)	Strain
0	0.028
4	0.036
8	0.041
12	0.044
16	0.047
20	0.050
24	0.052
28	0.053
32	0.055
36	0.056
40	0.058
44	0.059
48	0.061
52	0.062
56	0.064
60	0.066
64	0.067

Time (hrs)	Strain
68	0.069
72	0.070
76	0.072
80	0.073
84	0.075
88	0.076
92	0.078
96	0.080
100	0.082
104	0.084
108	0.087
112	0.090
116	0.095
120	0.100
124	0.106
128	0.113
132	0.124
	Failure

1. Plot the data on the graph provided. (5pts)

2. Indicate the areas on the graph that represent primary, secondary, and tertiary creep. (1 pt)

3. Determine the minimum creep rate for this material. Show work. (2 pts)

4. If the melting point of copper is 1085°C, what is the minimum temperature (in °C) that you would expect to observe creep in copper? (1 pt)

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5. Determine the length of the wire at failure. Show work. (2 pts)

6. How does the creep rate change during stage I (primary creep)? What is the main reason for this? (2 pts)

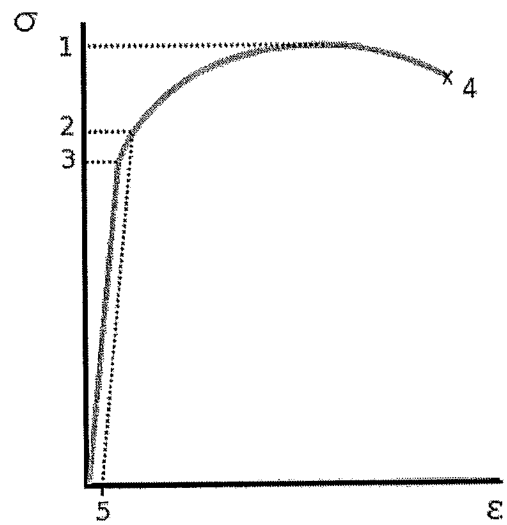
7. Draw a new curve on the same graph that represents the creep curve of the same material but at 500°C rather than 350°C. (2 pts)

B. Other Mechanical Properties Questions

8. A piece of copper originally at 305mm long is pulled in tension with a stress of 276 MPa. If the deformation is entirely elastic, what will be the resultant elongation? (Young's modulus for copper is 110. GPa) (3 pts)

9. What will be the length of the above wire when the stress is removed? (1 pt)

10. On the stress/strain diagram below, correctly label points 1-5. (5 pts)



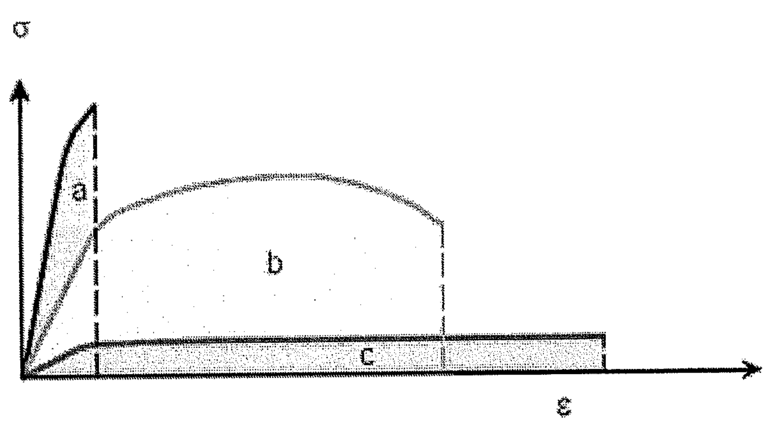
11. The diagram below shows the stress/strain curves of three different materials to fracture. One is a metal, one is a polymer, and one is a ceramic.

a. Assign the correct material to each curve. (3 pts)

b. Which is the strongest? (1 pt)

c. Which is the most ductile? (1 pt)

d. Which has the most material toughness? (1pt)



Part 2: Polymers

A. Making Putty

Procedure:

- Wear gloves.
- Pour 20 ml of the Elmer's glue solution into a plastic cup.
- Add 10 ml of the cross-linker (borax solution).
- Immediately begin stirring the solutions together using the wooden stick.
- After a couple of minutes of mixing, the putty should be taken out of the cup and kneaded in the hands. Don't worry about the material sticking to your gloves as these pieces will soon mix with the larger quantity with which you are working. Continue to knead until the material is no longer watery and can keep its shape when formed into a ball.
- The putty is non-toxic and safe to handle so you can put it in a zip-lock bag and take it home.

Questions

1. What happens to the properties of the product after it is immersed (in the Ziploc bag) into ice water for 60 sec? Why? (2 pts)

2. What happens to the properties of the product after it is immersed (in the Ziploc bag) into hot water for 60 sec? Why? (2 pts)

3. What happens when a balled up sample of the product is dropped onto the ground from shoulder height? (1 pt)

4. What happens when a balled up sample of the product is allowed to sit on the table for 30 sec? (1 pt)

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5. What happens when a sample of the product is pulled apart slowly? (1 pt)

6. What happens when a sample of the product is pulled apart quickly? (1 pt)

7. Describe the difference between a Newtonian fluid and a non-Newtonian fluid. Which one is this? Use observations to support your answer. (6 pts)

B. Balloon

Rubber balloons are most usually made of vulcanized latex polymers.

8. Draw a picture of the molecular structure of relaxed balloon rubber. (No atomic detail is necessary. Just lines and labels as necessary. Underneath your drawing, write 1-2 sentences describing the important factors that your drawing is trying to depict.) (3 pts)

9. Draw a second picture of balloon rubber which has been stretched out to 2-3 times its original length. (No atomic detail is necessary. Just lines and labels as necessary. Underneath your drawing, write 1-2 sentences describing the important factors that your drawing is trying to depict.) (3 pts)

10. Hold one end of a relaxed balloon in each hand a few inches in front of your nose. Quickly(!) stretch the balloon as far as you can and then touch the balloon to your forehead or cheek. Record your observations here. (1 pt)

11. Hold one end of a fully stretched balloon in each hand a few inches in front of your nose. Quickly(!) relax the balloon and then touch it to your forehead or cheek. Record your observations here. (1 pt)

(continued on the next page)

12. Inflate the balloon until it is about the size of a cantaloupe. Tie off the end of the balloon. (Ask for help if you need it.) Use your fingers to place a thin film of petroleum jelly onto a skewer. With a twisting motion, pierce the balloon with the skewer near the knot. Pass the skewer all the way through the balloon until it exits opposite to the knot. Record your observations here. (1 pt)

13. If you tried to pass a second skewer through the balloon at a right angle to the first one, what would you expect to happen? (1 pt)

14. With reference to your two drawings, explain the three phenomena you just observed (steps 10, 11, and 12) in terms of the structure of polymers. (6 pts)

Part III: Crystal Structures

A. Metallic Crystal Lattices

1. The metal manganese has a simple cubic structure. If the manganese atom has a radius of 0.112nm, what is the volume of a unit cell of Manganese? Show work. (2 pts)

How many atoms are there in a unit cell of Manganese? (1 pt)

What is the volume of Manganese atoms contained in a unit cell? Show work. (2 pts)

What is the packing efficiency of the Manganese crystal lattice? Show work. (2 pts)

2. At 1042°C metal X undergoes a change from a BCC to a FCC arrangement. The density of a metallic solid can be given by

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

where

n = number of atoms associated with each unit cell
A = molar mass
V_c = volume of the unit cell
N_A = Avogadro's number 6.023×10^{23}

a. If the density of X at room temperature is 9.57 g/cm^3 and it's molar mass is 155.62 g/mol (completely fictitious) determine the atomic radius of X. Only answers with all supporting work will be accepted. (5 pts)

b. Using the radius of X that you calculated above (and assuming it remains constant), calculate the new density of X at 1042°C. (3 pts)

B. Ionic Crystal Lattices

Ionic crystal lattices can most often be thought of as either simple cubic or face centered cubic arrays of anions with cations occupying either some or all of the cubic, tetrahedral, or octahedral holes within them. This is governed not only by the stoichiometric ratio of cations to anions but also by the "radius ratio rule" whereby the radii of the cations (r+) and anions (r-) are compared using the following table.

If r+/r- is...	then the anions are arranged in...	and the cations occupy...
x>0.732	SC	Cubic holes
0.732>x>0.414	FCC	Octahedral holes
0.414>x>0.235	FCC	Tetrahedral holes

3. Using the ionic radius data given, determine which of the following situations (A-H) apply for each of the ionic crystals listed below. Answer choices may be used more than once. (10 pts)

A. SC anions with all of the cubic holes occupied by cations
B. SC anions with 1/2 of the cubic holes occupied by cations

C. FCC anions with all of the octahedral holes occupied by cations
D. FCC anions with 1/2 of the octahedral holes occupied by cations
E. FCC anions with 1/4 of the octahedral holes occupied by cations

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F. FCC anions with all of the tetrahedral holes occupied by cations
G. FCC anions with 1/2 of the tetrahedral holes occupied by cations
H. FCC anions with 1/4 of the tetrahedral holes occupied by cations

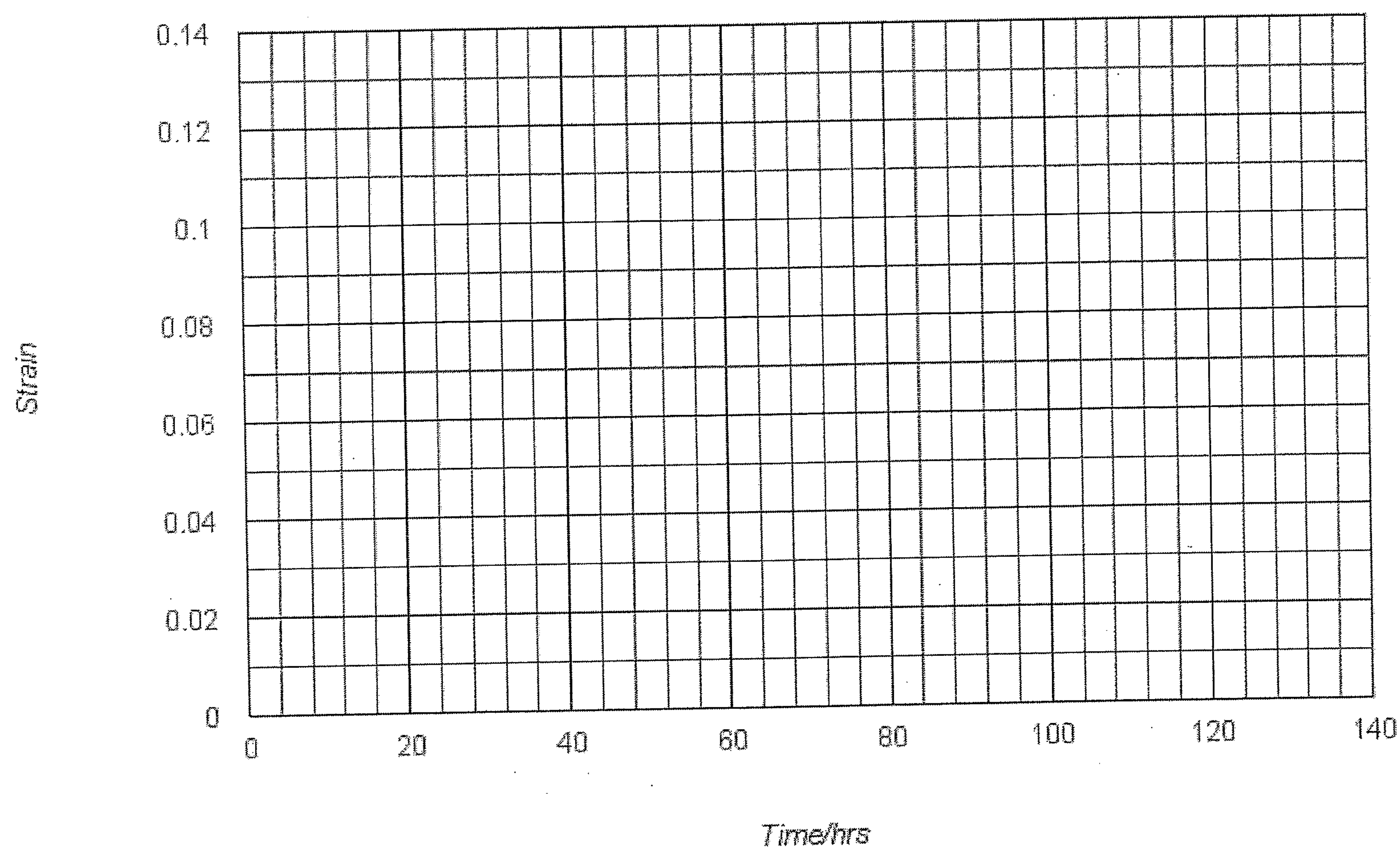
Ionic Crystals

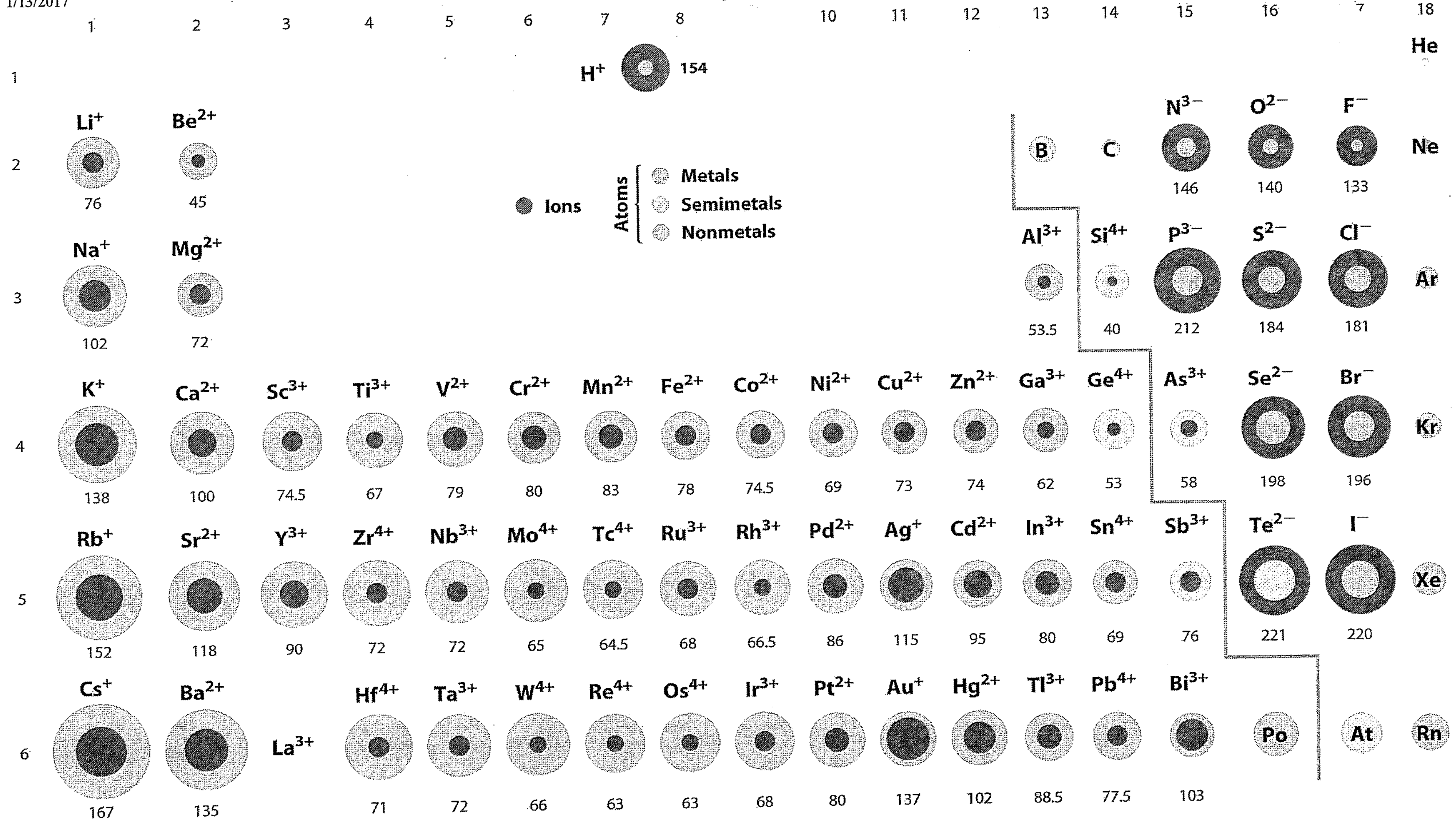
a) NaCl ____
b) Li_2S ____
c) BaO ____
d) LiBr ____ (*)
e) $CdCl_2$ ____

4. Modeling an ionic crystal lattice (5 pts)

- Using the Styrofoam balls (bromides) and blue bead(s) (lithium ions) provided, make a unit cell model of the ionic crystal LiBr.
- Attach the Styrofoam balls together with the toothpicks (careful they're sharp!) and place the blue bead(s) in the appropriate position(s).
- Under no circumstances can you alter any of the Styrofoam balls other than by sticking toothpicks through them. It is okay that some parts of some of your balls might fall outside of the unit cell.
- When you are done, write your school name and team number on the "flag" and bring your model to the front of the room for grading.

Strain vs Time




1
2
3
4
5
6
7
8
10
11
12
13
14
15
16
7
18
1
H+
154
He
2
Li+
76
Be2+
45
Ions
Atoms
Metals
Semimetals
Nonmetals
B
C
N3−
146
O2−
140
F−
133
Ne
3
Na+
102
Mg2+
72
Al3+
53.5
Si4+
40
P3−
212
S2−
184
Cl−
181
Ar
4
K+
138
Ca2+
100
Sc3+
74.5
Ti3+
67
V2+
79
Cr2+
80
Mn2+
83
Fe2+
78
Co2+
74.5
Ni2+
69
Cu2+
73
Zn2+
74
Ga3+
62
Ge4+
53
As3+
58
Se2−
198
Br−
196
Kr
5
Rb+
152
Sr2+
118
Y3+
90
Zr4+
72
Nb3+
72
Mo4+
65
Tc4+
64.5
Ru3+
68
Rh3+
66.5
Pd2+
86
Ag+
115
Cd2+
95
In3+
80
Sn4+
69
Sb3+
76
Te2−
221
I−
220
Xe
6
Cs+
167
Ba2+
135
La3+
Hf4+
71
Ta3+
72
W4+
66
Re4+
63
Os4+
63
Ir3+
68
Pt2+
80
Au+
137
Hg2+
102
Tl3+
88.5
Pb4+
77.5
Bi3+
103
Po
At
Rn

Periodic Table of the Elements

Chemistry Reference Sheet

California Standards Test

Key

11	Atomic number
Na	Element symbol
Sodium	Element name
22.99	Average atomic mass*

	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 H Hydrogen 1.01																	2 He Helium 4.00
2	3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
3	11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
6	55 Cs Cesium 132.91	56 Ba Barium 137.33	57 La Lanthanum 138.91	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)									

58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

* If this number is in parentheses, then it refers to the atomic mass of the most stable isotope.