

Programming and Data Structures
Test 2

You are provided with a program (**Test.java**) that uses an array list to store tuples representing the chemical elements. The tuple class is also provided as a generic class (**Tuple.java**) with four generic types **E1**, **E2**, **E3**, and **E4**.

The test program uses 4-tuple objects for the types **Integer**, **String**, **String**, and **Double** representing the **atomic number**, **name**, **symbol**, and **atomic mass** of a chemical element. These tuples are stored in an array list populated with the data from the file `elements.txt`. The program allows the user to search for a chemical element by symbol, to sort the elements using two different criteria: by number or by symbol, and displays the chemical element with the largest atomic mass.

You are asked to complete the following tasks:

1. Define a generic search method to look for a tuple in an array list of tuples as described by the following header:

```
public static <E1, E2, E3, E4> int  
search(ArrayList<Tuple<E1, E2, E3, E4>> list, E3 key)
```

The method returns the index of the tuple that has its third element equal to **key**.

[search must be a recursive method.](#)

2. Define a generic method to find the tuple with the largest value of the fourth element, in a given list as described by the header below:

```
public static <E1, E2, E3, E4> int  
find_Max(ArrayList<Tuple<E1, E2, E3, E4>> list)
```

The method returns the index of the tuple that has the largest fourth element.

3. In order to allow the program to sort the chemical elements using two different criteria (either the atomic number (the first element of a tuple) or the symbol (the third element of a tuple)), define two classes that implement the interface **Comparator** for each criterion, called **ComparatorByFirst** and **ComparatorByThird**. *Once these two classes have been defined, uncomment the lines 25 and 30 in the file **Test.java**.*
4. Determine the time complexity of the methods **search** and **findMax** using Big-O notation. Add the time complexity as a comment before the method header.

Submit the files **Test.java**, **Tuple.java**, **ComparatorByFirst.java**, and **ComparatorByThird.java** on course site. Javadoc comments are not required.

Sample runs of the program are provided below for testing.

----- Sample run 1 -----

Enter the symbol of an element: Na

Element found: (11, Sodium, Na, 22.9897)

Select the sort criterion (number/symbol): symbol

(89, Actinium, Ac, 227.0)
(47, Silver, Ag, 107.8682)
(13, Aluminum, Al, 26.9815)
(95, Americium, Am, 243.0)
(19, Argon, Ar, 39.948)
(33, Arsenic, As, 78.9216)
(85, Astatine, At, 210.0)
(79, Gold, Au, 196.9665)
(5, Boron, B, 10.811)
(56, Barium, Ba, 137.327)
(4, Beryllium, Be, 9.0122)
(107, Bohrium, Bh, 264.0)
(83, Bismuth, Bi, 208.9804)
(97, Berkelium, Bk, 247.0)
(35, Bromine, Br, 79.904)
(6, Carbon, C, 12.0107)
(20, Calcium, Ca, 40.078)
(48, Cadmium, Cd, 112.411)
(58, Cerium, Ce, 140.116)
(98, Californium, Cf, 251.0)
(17, Chlorine, Cl, 35.453)
(96, Curium, Cm, 247.0)
(27, Cobalt, Co, 58.9332)
(24, Chromium, Cr, 51.9961)
(55, Cesium, Cs, 132.9055)
(29, Copper, Cu, 63.546)
(105, Dubnium, Db, 262.0)
(66, Dysprosium, Dy, 162.5)
(68, Erbium, Er, 167.259)
(99, Einsteinium, Es, 252.0)
(63, Europium, Eu, 151.964)
(9, Fluorine, F, 18.9984)
(26, Iron, Fe, 55.845)
(100, Fermium, Fm, 257.0)
(87, Francium, Fr, 223.0)
(31, Gallium, Ga, 69.723)
(64, Gadolinium, Gd, 157.25)
(32, Germanium, Ge, 72.64)
(1, Hydrogen, H, 1.0079)
(2, Helium, He, 4.0026)

(72, Hafnium, Hf, 178.49)
(80, Mercury, Hg, 200.59)
(67, Holmium, Ho, 164.9303)
(108, Hassium, Hs, 277.0)
(52, Iodine, I, 126.9045)
(49, Indium, In, 114.818)
(77, Iridium, Ir, 192.217)
(18, Potassium, K, 39.0983)
(36, Krypton, Kr, 83.8)
(57, Lanthanum, La, 138.9055)
(3, Lithium, Li, 6.941)
(103, Lawrencium, Lr, 262.0)
(71, Lutetium, Lu, 174.967)
(101, Mendelevium, Md, 258.0)
(12, Magnesium, Mg, 24.305)
(25, Manganese, Mn, 54.938)
(42, Molybdenum, Mo, 95.94)
(109, Meitnerium, Mt, 268.0)
(7, Nitrogen, N, 14.0067)
(11, Sodium, Na, 22.9897)
(41, Niobium, Nb, 92.9064)
(60, Neodymium, Nd, 144.24)
(10, Neon, Ne, 20.1797)
(28, Nickel, Ni, 58.6934)
(102, Nobelium, No, 259.0)
(93, Neptunium, Np, 237.0)
(8, Oxygen, O, 15.9994)
(76, Osmium, Os, 190.23)
(15, Phosphorus, P, 30.9738)
(91, Protactinium, Pa, 231.0359)
(82, Lead, Pb, 207.2)
(46, Palladium, Pd, 106.42)
(61, Promethium, Pm, 145.0)
(84, Polonium, Po, 209.0)
(59, Praseodymium, Pr, 140.9077)
(78, Platinum, Pt, 195.078)
(94, Plutonium, Pu, 244.0)
(88, Radium, Ra, 226.0)
(37, Rubidium, Rb, 85.4678)
(75, Rhenium, Re, 186.207)
(104, Rutherfordium, Rf, 261.0)
(111, Roentgenium, Rg, 272.0)
(45, Rhodium, Rh, 102.9055)
(86, Radon, Rn, 222.0)
(44, Ruthenium, Ru, 101.07)

(16, Sulfur, S, 32.065)
(51, Antimony, Sb, 121.76)
(21, Scandium, Sc, 44.9559)
(34, Selenium, Se, 78.96)
(106, Seaborgium, Sg, 266.0)
(14, Silicon, Si, 28.0855)
(62, Samarium, Sm, 150.36)
(50, Titanium, Sn, 118.71)
(38, Strontium, Sr, 87.62)
(73, Tantalum, Ta, 180.9479)
(65, Terbium, Tb, 158.9253)
(43, Technetium, Tc, 98.0)
(53, Tellurium, Te, 127.6)
(90, Thorium, Th, 232.0381)
(22, Titanium, Ti, 47.867)
(81, Thallium, Tl, 204.3833)
(69, Thulium, Tm, 168.9342)
(92, Uranium, U, 238.0289)
(23, Vanadium, V, 50.9415)
(74, Tungsten, W, 183.84)
(54, Xenon, Xe, 131.293)
(39, Yttrium, Y, 88.9059)
(70, Ytterbium, Yb, 173.04)
(30, Zinc, Zn, 65.39)
(40, Zirconium, Zr, 91.224)

The element with the largest atomic mass: (108, Hassium, Hs, 277.0)

----- Sample run 2 -----

Enter the symbol of an element: P

Element found: (15, Phosphorus, P, 30.9738)

Select the sort criterion (number/symbol): number

(1, Hydrogen, H, 1.0079)
(2, Helium, He, 4.0026)
(3, Lithium, Li, 6.941)
(4, Beryllium, Be, 9.0122)
(5, Boron, B, 10.811)
(6, Carbon, C, 12.0107)
(7, Nitrogen, N, 14.0067)
(8, Oxygen, O, 15.9994)
(9, Fluorine, F, 18.9984)
(10, Neon, Ne, 20.1797)
(11, Sodium, Na, 22.9897)
(12, Magnesium, Mg, 24.305)
(13, Aluminum, Al, 26.9815)
(14, Silicon, Si, 28.0855)
(15, Phosphorus, P, 30.9738)
(16, Sulfur, S, 32.065)
(17, Chlorine, Cl, 35.453)
(18, Potassium, K, 39.0983)
(19, Argon, Ar, 39.948)
(20, Calcium, Ca, 40.078)
(21, Scandium, Sc, 44.9559)
(22, Titanium, Ti, 47.867)
(23, Vanadium, V, 50.9415)
(24, Chromium, Cr, 51.9961)
(25, Manganese, Mn, 54.938)
(26, Iron, Fe, 55.845)
(27, Cobalt, Co, 58.9332)
(28, Nickel, Ni, 58.6934)
(29, Copper, Cu, 63.546)
(30, Zinc, Zn, 65.39)
(31, Gallium, Ga, 69.723)
(32, Germanium, Ge, 72.64)
(33, Arsenic, As, 78.9216)
(34, Selenium, Se, 78.96)
(35, Bromine, Br, 79.904)
(36, Krypton, Kr, 83.8)
(37, Rubidium, Rb, 85.4678)
(38, Strontium, Sr, 87.62)
(39, Yttrium, Y, 88.9059)
(40, Zirconium, Zr, 91.224)

(41, Niobium, Nb, 92.9064)
(42, Molybdenum, Mo, 95.94)
(43, Technetium, Tc, 98.0)
(44, Ruthenium, Ru, 101.07)
(45, Rhodium, Rh, 102.9055)
(46, Palladium, Pd, 106.42)
(47, Silver, Ag, 107.8682)
(48, Cadmium, Cd, 112.411)
(49, Indium, In, 114.818)
(50, Titanium, Sn, 118.71)
(51, Antimony, Sb, 121.76)
(52, Iodine, I, 126.9045)
(53, Tellurium, Te, 127.6)
(54, Xenon, Xe, 131.293)
(55, Cesium, Cs, 132.9055)
(56, Barium, Ba, 137.327)
(57, Lanthanum, La, 138.9055)
(58, Cerium, Ce, 140.116)
(59, Praseodymium, Pr, 140.9077)
(60, Neodymium, Nd, 144.24)
(61, Promethium, Pm, 145.0)
(62, Samarium, Sm, 150.36)
(63, Europium, Eu, 151.964)
(64, Gadolinium, Gd, 157.25)
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(66, Dysprosium, Dy, 162.5)
(67, Holmium, Ho, 164.9303)
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(69, Thulium, Tm, 168.9342)
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(72, Hafnium, Hf, 178.49)
(73, Tantalum, Ta, 180.9479)
(74, Tungsten, W, 183.84)
(75, Rhenium, Re, 186.207)
(76, Osmium, Os, 190.23)
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(80, Mercury, Hg, 200.59)
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(82, Lead, Pb, 207.2)
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(96, Curium, Cm, 247.0)
(97, Berkelium, Bk, 247.0)
(98, Californium, Cf, 251.0)
(99, Einsteinium, Es, 252.0)
(100, Fermium, Fm, 257.0)
(101, Mendelevium, Md, 258.0)
(102, Nobelium, No, 259.0)
(103, Lawrencium, Lr, 262.0)
(104, Rutherfordium, Rf, 261.0)
(105, Dubnium, Db, 262.0)
(106, Seaborgium, Sg, 266.0)
(107, Bohrium, Bh, 264.0)
(108, Hassium, Hs, 277.0)
(109, Meitnerium, Mt, 268.0)
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The element with the largest atomic mass: (108, Hassium, Hs, 277.0)