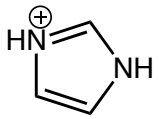
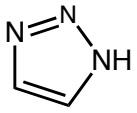
Short questions (1-4; 3 points each) Name_____

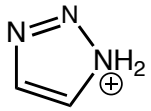
1. Which <u>one</u> of the following heterocycles does NOT show aromatic stabilization in the ionization state indicated?



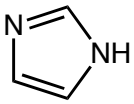
A



B



C



D

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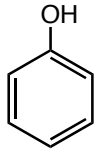
2. What is the approximate energy of the aromatic stabilization of benzene?
IDENTIFY THE VALUE AND THE CORRECT UNITS

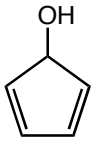
A	B	C	D
10 cal/mol	35 kcal/mol	35 cal/mol	10 kcal/mol

---

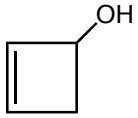
3. Which of the following compounds is MOST likely to lose H_2O upon treatment with H_2SO_4 (a source of H^+)?



A



B



C

D

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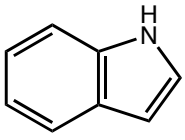
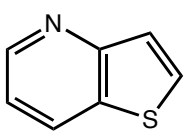
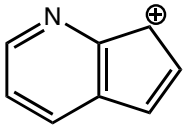
4. Which ONE of the following is NOT a 10-electron AROMATIC system?



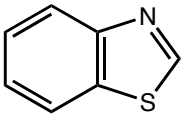
A



B



C

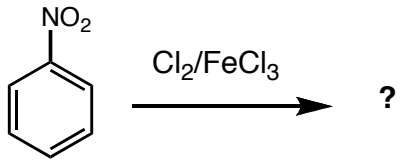


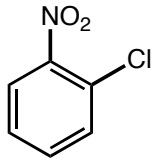
D

score

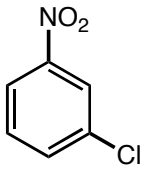
Short questions (5-6; 4 points each) Name_____

5. Identify the MAJOR product of the reaction shown?

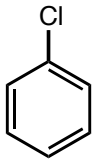




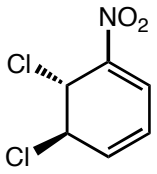
A



B



C



D

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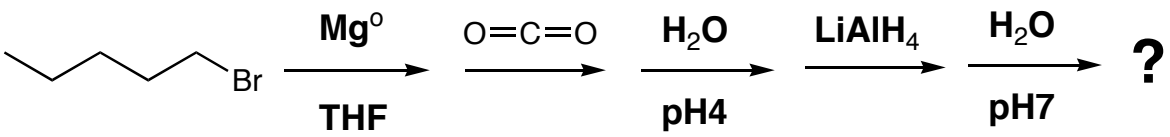
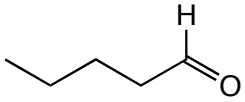
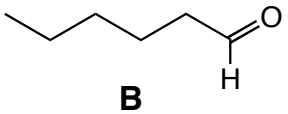
6. What is the FINAL product of the reaction sequence shown below?

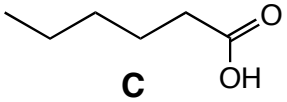




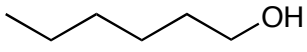
A



B



C

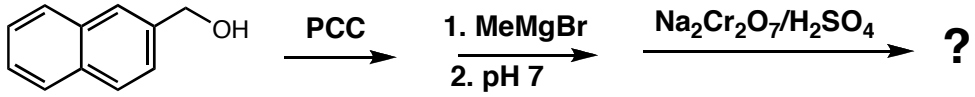


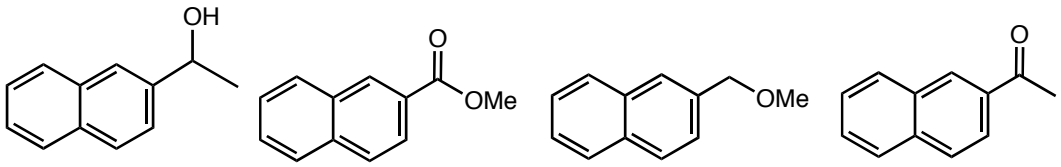
D

score

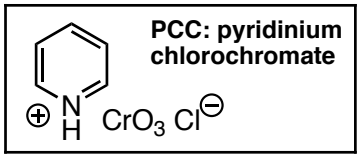
Short questions (7-8; 4 points each) Name _____

7. What is the FINAL product of the reaction sequence shown?





A **B** **C** **D**



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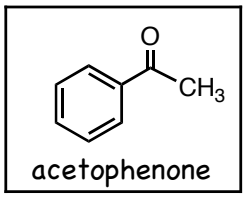
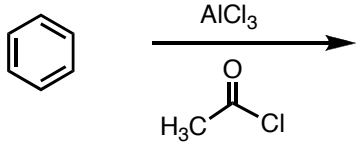
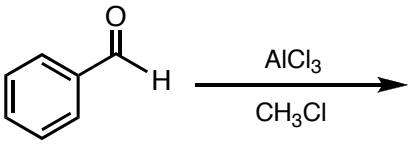
8. Which of the following reaction sequences does NOT give acetophenone as the MAJOR product?



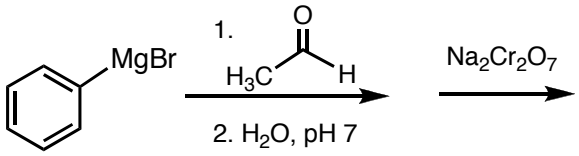
A



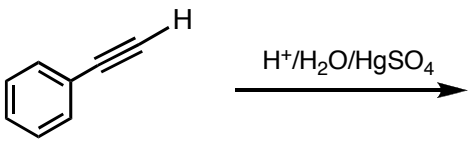
B



C



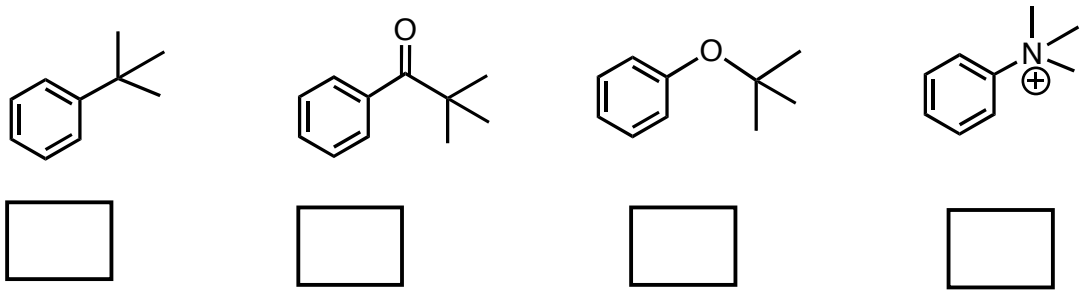
D



score

Short questions (9-10; 4 points each) Name_____

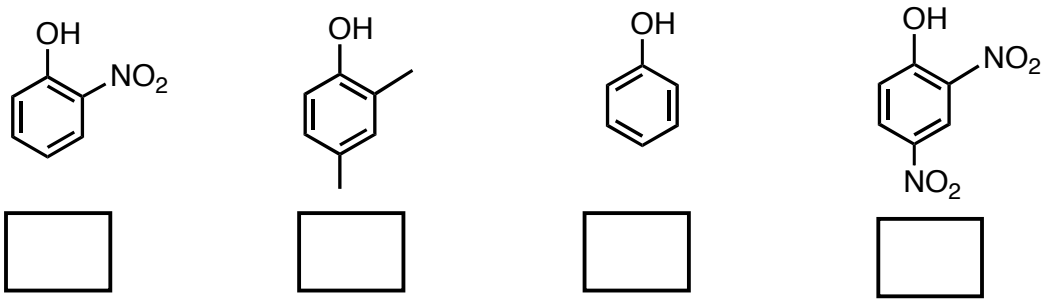
9. Rank the following compounds in order of reactivity in <u>ELECTROPHILIC</u> aromatic substitution.



Rank the MOST REACTIVE as 1 and the LEAST REACTIVE as 4

---

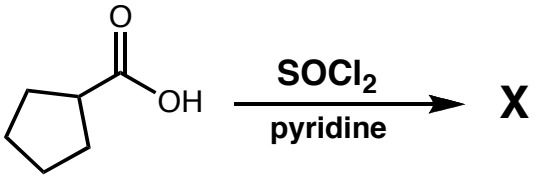
10. Rank the following in terms of acidity. Show the MOST ACIDIC as 1 and the LEAST ACIDIC as 4.

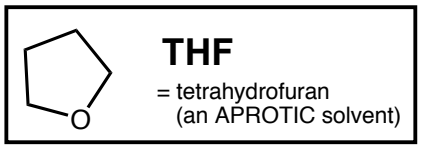


score

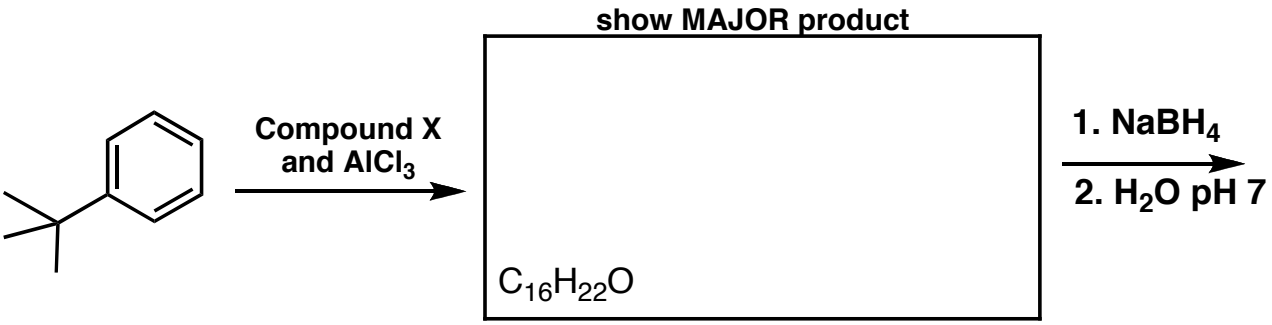
Long questions (points as indicated) Name _____

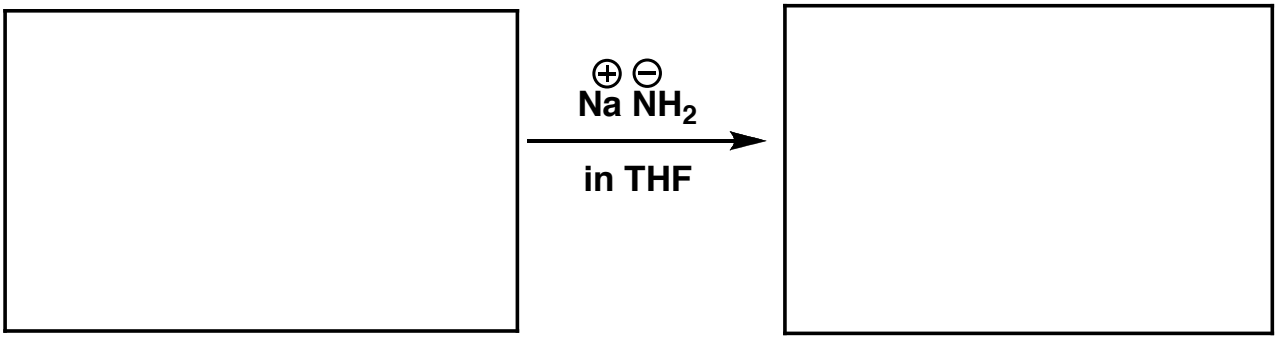
11. (12 points) Give the structures of the compounds in the boxes.

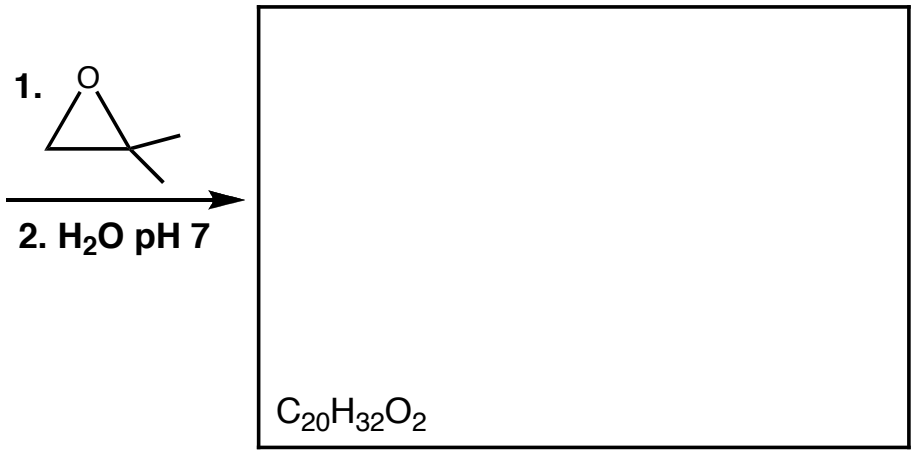




show MAJOR product



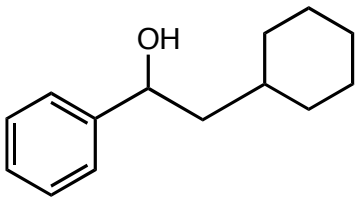




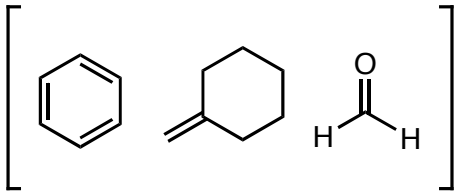
Make sure that the molecular formulas match your answer wherever they are provided!

score

12. (18 points) Design a synthesis of compound Z.
The ONLY carbon-containing starting materials that you can use are shown in the square brackets next to the target. You may use any other common reagents (e.g. oxidants, reductants, Lewis acids, metals, and thionyl chloride) and solvents. NO need to show mechanisms!



Z

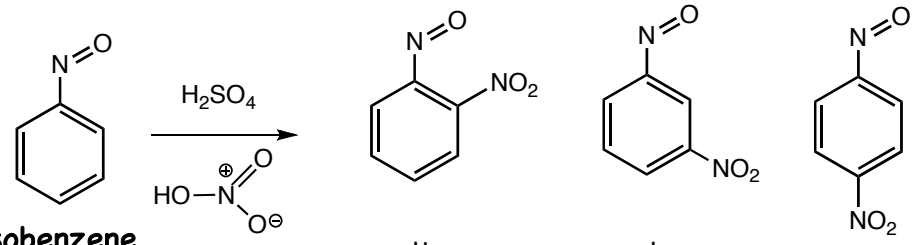


Note: A retrosynthetic analysis will be useful for figuring this problem out.

score

13. (18 points) Nitrosobenzene undergoes electrophilic aromatic substitution (EAS) when treated with nitric acid and sulfuric acid. (This question continues on p.9 and 10.)

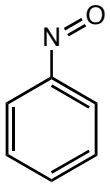
a) (12 points) DEDUCE whether the nitroso group is "ortho/para" OR "meta" directing by comparing the mechanisms for para and meta substitution.



nitrosobenzene ortho meta para

For full credit you must show the detailed stepwise mechanism, including all arrows, the structure of the electrophile and all of the resonance structures for the key intermediates. Be sure to show all three steps in the EAS reaction.

Mechanism for para substitution:

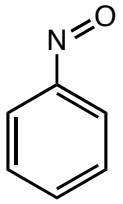


score

Name_____

13 a) (contd.)

Mechanism for meta substitution



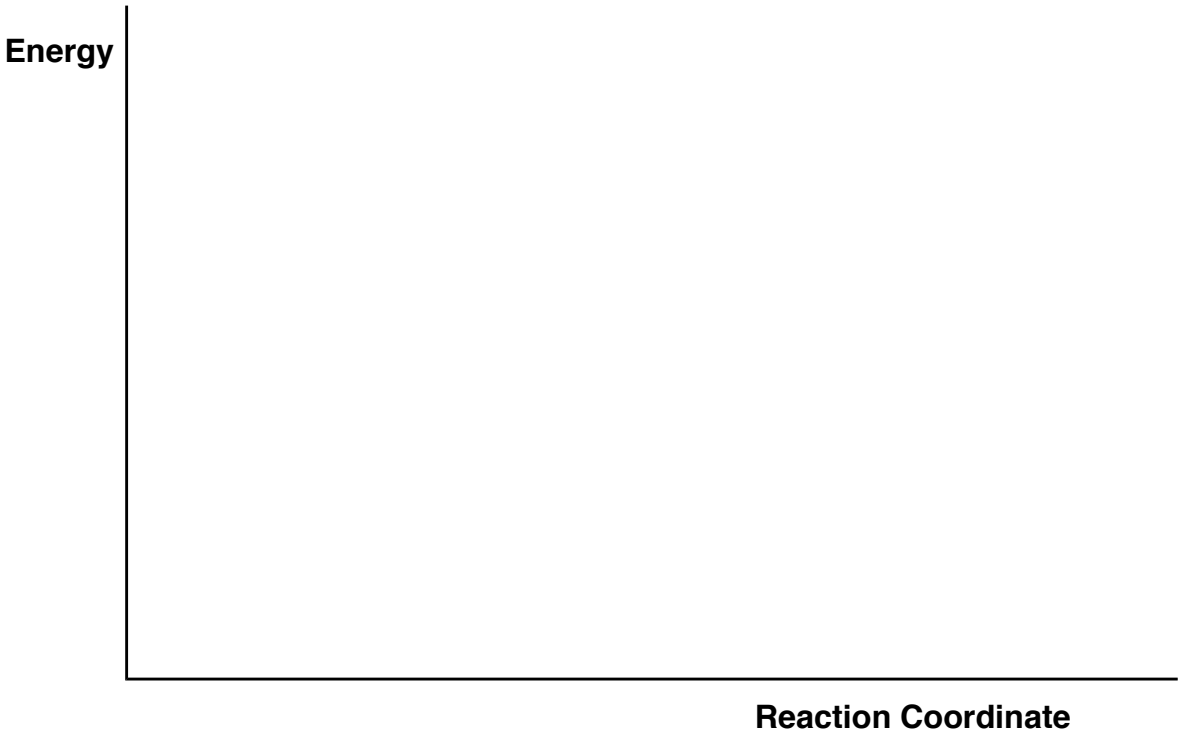
score

13. (contd. 6 points) b) Assuming that the OVERALL reaction is slightly EXOTHERMIC - construct an energy diagram for the EAS reaction of nitrosobenzene leading to the para- and meta-substituted products.

The diagram MUST show:

- The relative energies of the starting material, the σ-complexes and the products.

- The energies of activation for the rate determining steps of the para- and meta-directing EAS processes.



Note: No need to draw out structures - just labels such as SM, PROD, σ–COMPLEX. are fine.

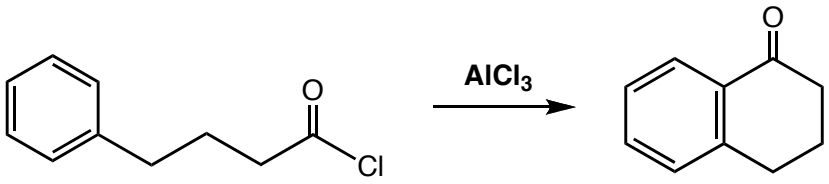
score

Long questions (Points as shown)

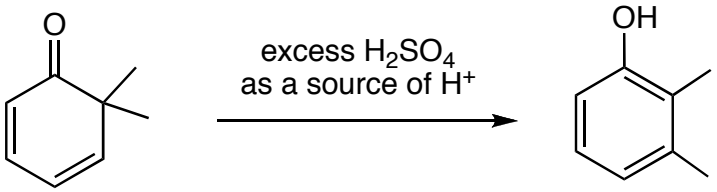
Name _____

15. (16 points) Provide the detailed stepwise mechanisms for the following transformations.

a.



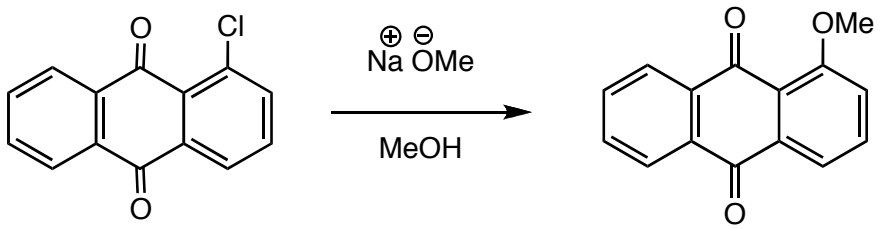
b.



score

15. Contd. (16 points) Provide the detailed stepwise mechanisms for the following transformations.

c.



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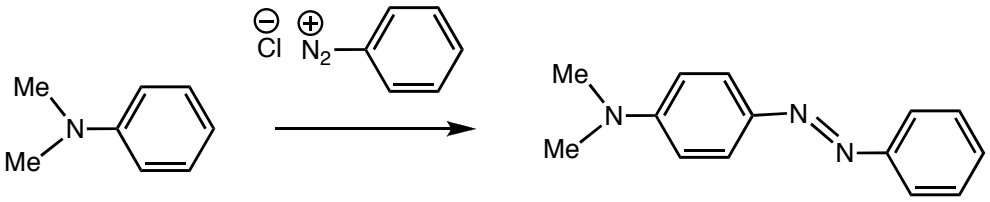
d.



Hint: Write out the Lewis structure for the compound above the arrow.

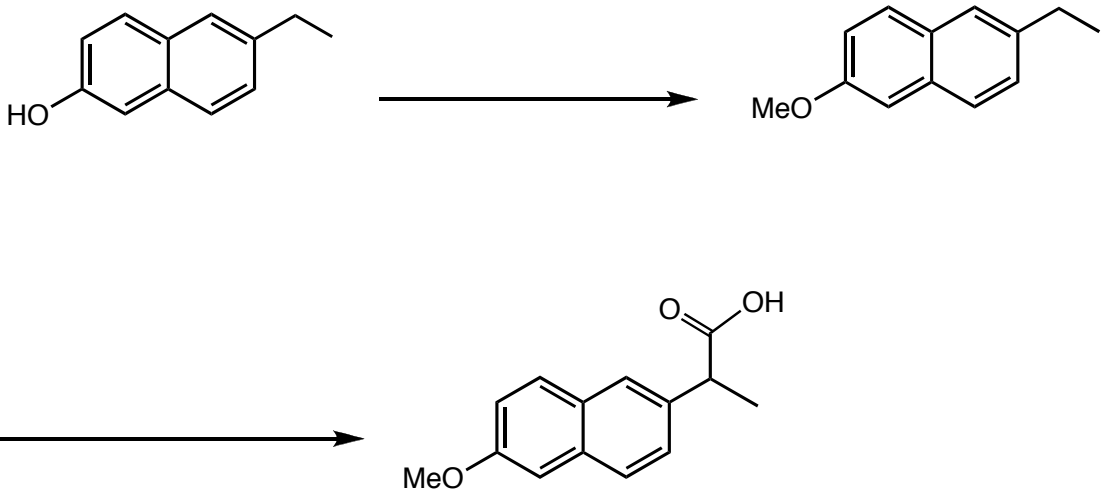
score

BONUS QUESTION (5 points)

Name _____

The following represents part of a synthetic route to Naproxen® (sold under the trade-name Aleve), which is an important anti-inflammatory agent.

Provide the best reagents for each transformation (more than one step may be required). No need to show mechanisms!

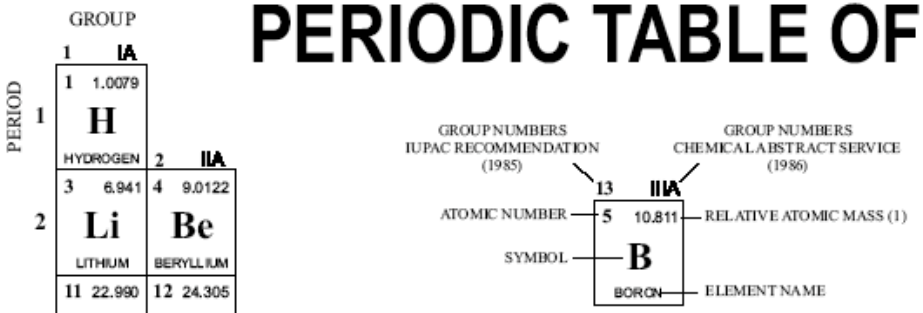


Naproxen®

score

PERIODIC TABLE OF THE ELEMENTS

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



PERIOD	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.

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Important Electronegativity Values

H 2.2						
Li 1.0	Be 1.6	B 1.8	C 2.5	N 3.0	O 3.4	F 4.0
Na 0.9	Mg 1.3	Al 1.6	Si 1.9	P 2.2	S 2.6	Cl 3.2
K 0.8						Br 3.0
						I 2.7

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