

CHEMISTRY 2500: Organic Chemistry I

MIDTERM-2

Friday, November 23, 2018

Instructions:

- This exam paper consists of 12 questions.
- The exam is worth a total of 56 marks. Most of these marks are for explanation/showing your work rather than for reaching the correct answer. Explain all of your answers fully using diagrams where appropriate (a picture really is worth a thousand words!).
- Marks will be deducted for poorly drawn structures.
- No calculators allowed. No other electronic devices can be present with you during the exam unless authorized by the instructor.
- You may use a molecular model kit.
- There is a 2-hour time limit.
- If your work is not legible, it will be given a mark of zero.
- **Read the questions carefully.** Good luck.

Confidentiality Agreement:

I agree not to discuss (or in any other way divulge) the contents of this exam until they have all been marked and returned. I understand that, if I were to break this agreement, I would be choosing to commit academic misconduct, a serious offense that will be punished. The minimum punishment would be a mark of 0 on this exam and removal of the "overwrite midterm mark with final exam mark" option for my grade in this course; the maximum punishment would include expulsion from this university.

Signature: _____

Date: _____

Course: CHEM 2500 (Organic Chemistry I)

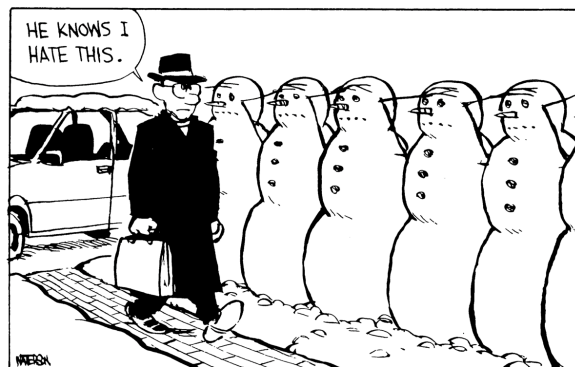
Semester: Fall 2018

The University of Lethbridge

Question Breakdown

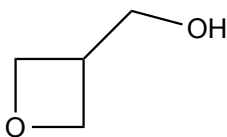
Q1	/6
Q2	/4
Q3	/4
Q4	/4
Q5	/4
Q6	/5
Q7	/5
Q8	/4
Q9	/6
Q10	/5
Q11	/5
Q12	/4

Total	/56
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1. Consider compound X with molecular formula $C_4H_8O_2$:

[6 marks]



Compound X ($C_4H_8O_2$)

(a) Draw a constitutional isomer that is approximately 1 trillion (10^{12}) times more acidic than the compound X.

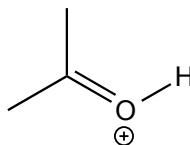
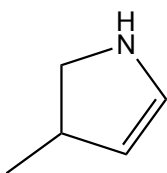
(b) Draw a constitutional isomer that is less acidic than the compound X.

(c) Draw a constitutional isomer that will have approximately the same acidity as the compound X.

2.

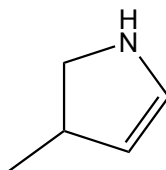
(a) Draw the conjugate base beside each of the following acids.

[4 marks]

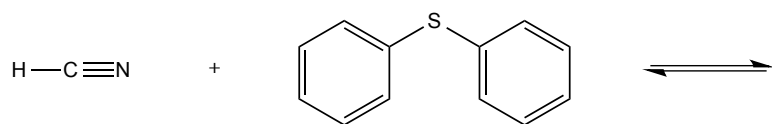


(b) Draw the conjugate acid beside each of the following bases.

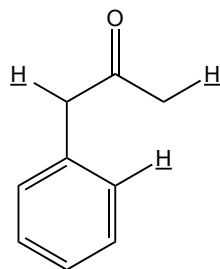
NaOH



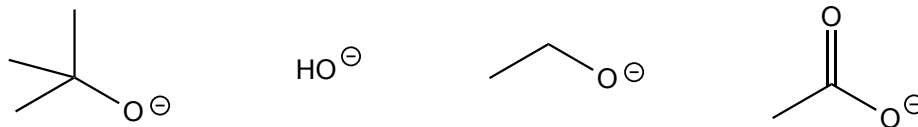
3. For the reactants below, identify the acid and base. Then draw the mechanistic arrows showing a proton transfer reaction. Draw the products of that proton transfer reaction and then predict the position of the equilibrium. **[4 marks]**



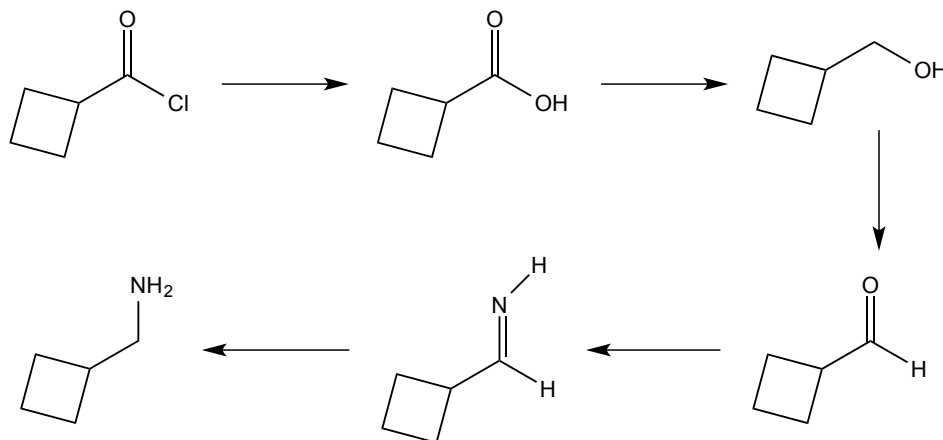
4. The molecule below has three protons which are underlined. Determine which of the three protons is more acidic. Explain your reasoning. **[4 marks]**



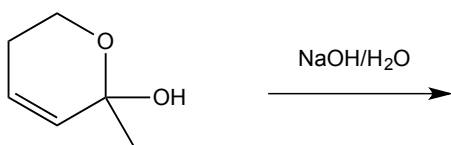
5. In the group of compounds below, circle the most basic compound. Explain your reasoning. **[4 marks]**



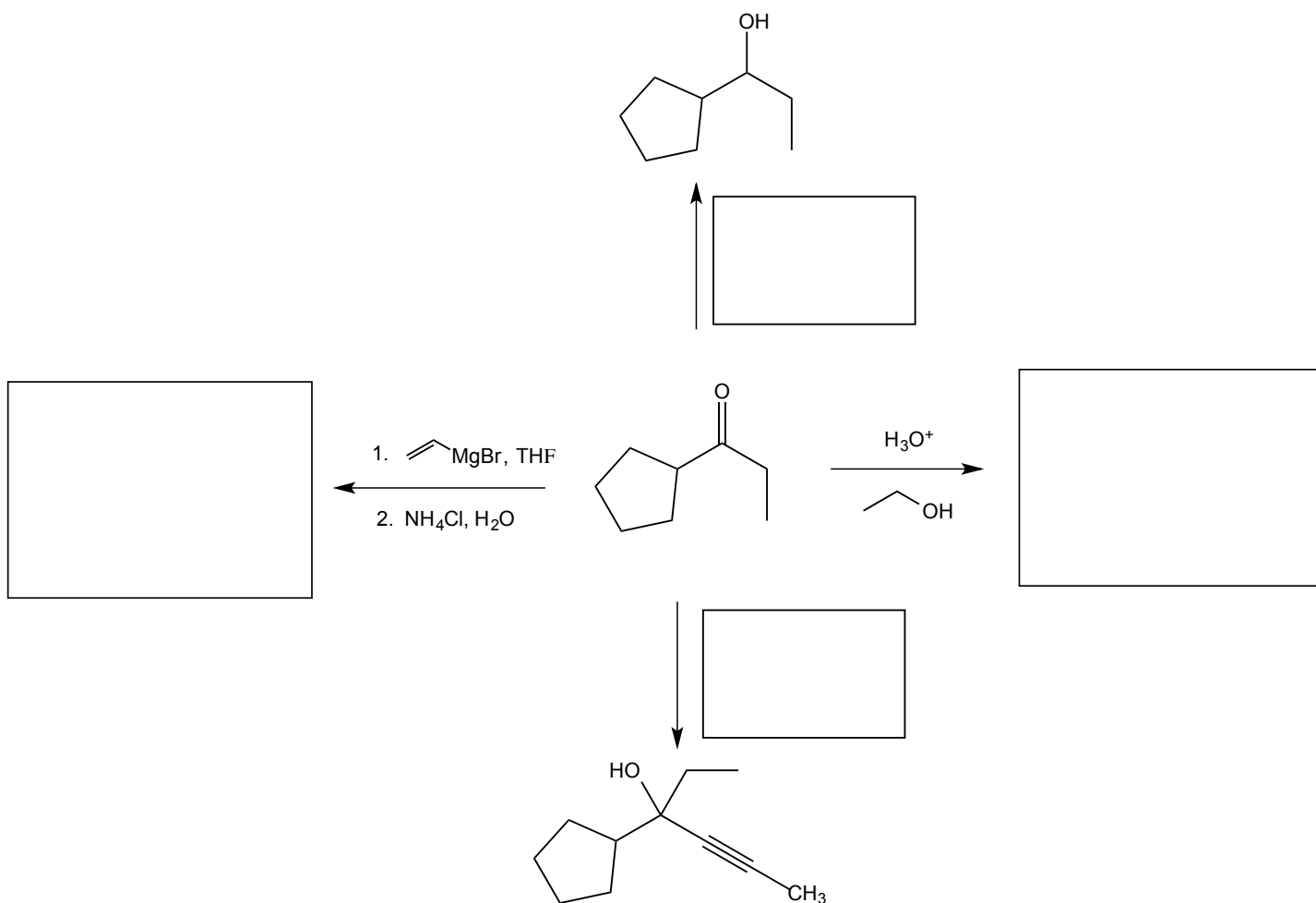
6. Over each arrow, classify each of the reactions in the following multistep sequence as an oxidation, a reduction, or neither. **[5 mark]**



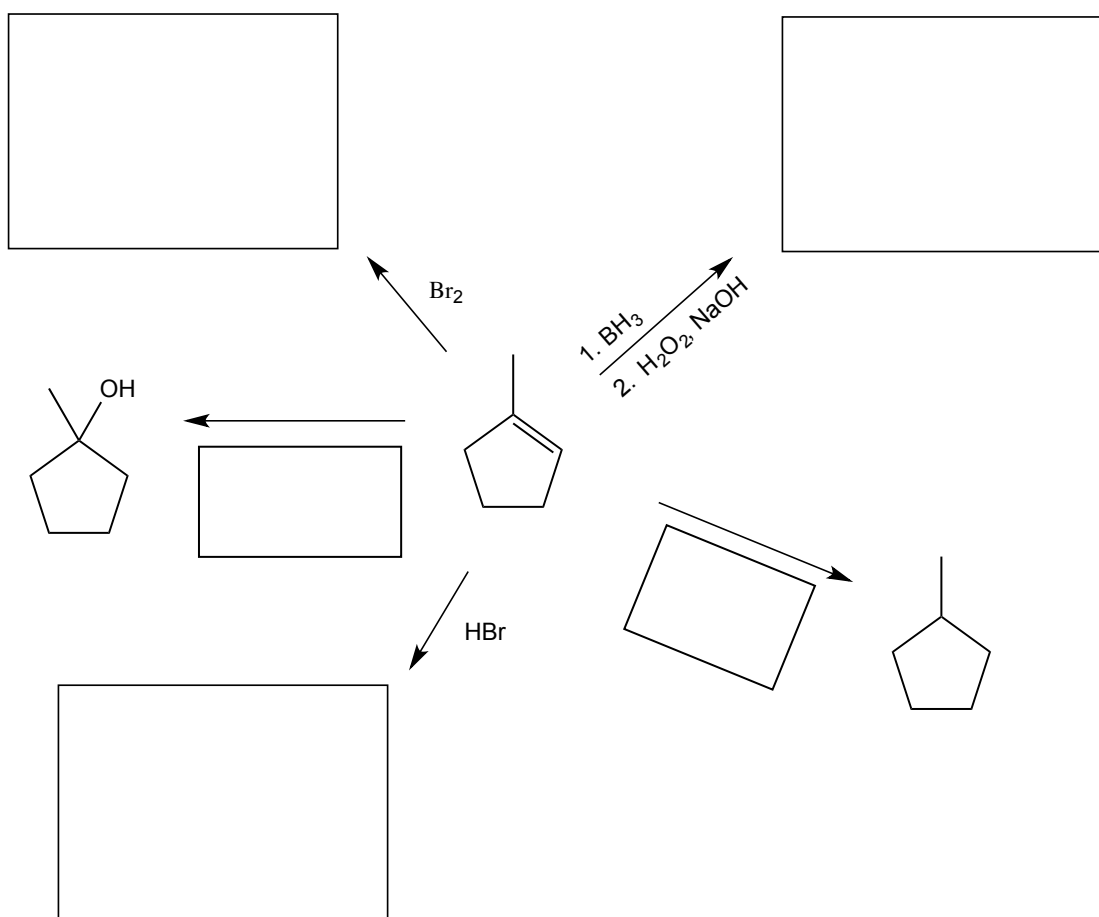
7. The following hemiacetal yields a carbonyl compound when treated with aqueous sodium hydroxide (NaOH). Using curved arrows, draw the mechanism of this reaction and determine the structure of the aldehyde or ketone that results. **[5 marks]**



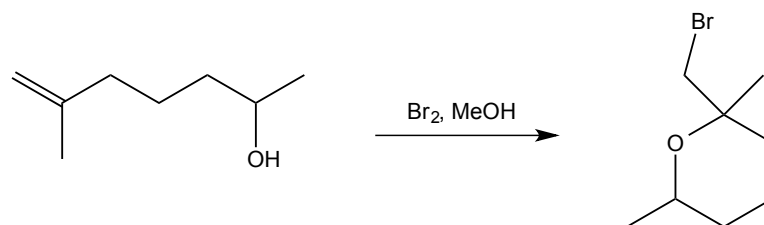
8. For the following reaction sequences, provide the missing reagents or products. **[4 marks]**



9. For each of the following reactions, fill in the missing reagents or products. For the products, be sure to indicate the correct stereochemistry where necessary. **[6 marks]**

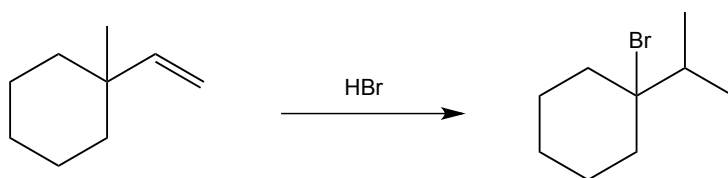


10. Use curved arrows to draw a plausible mechanism for the following reaction. **[5 marks]**

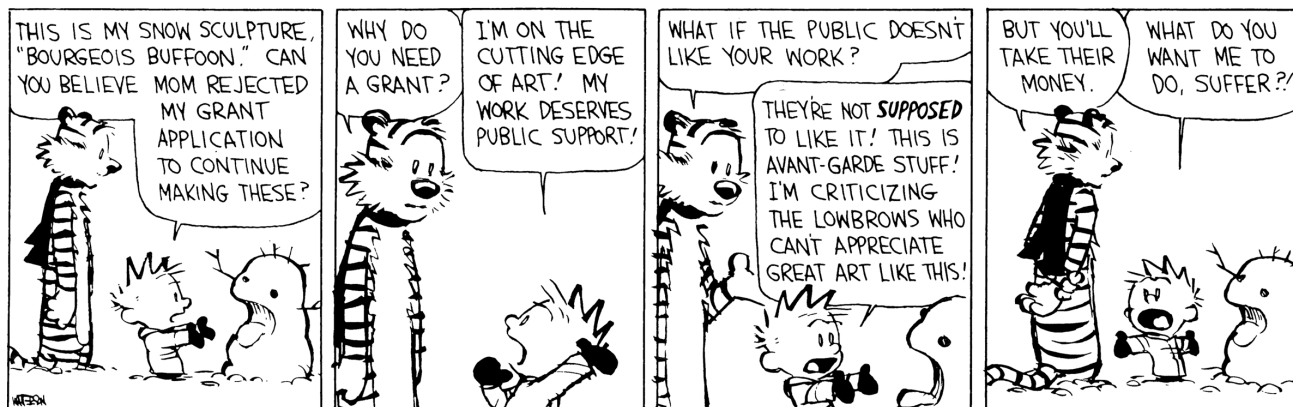
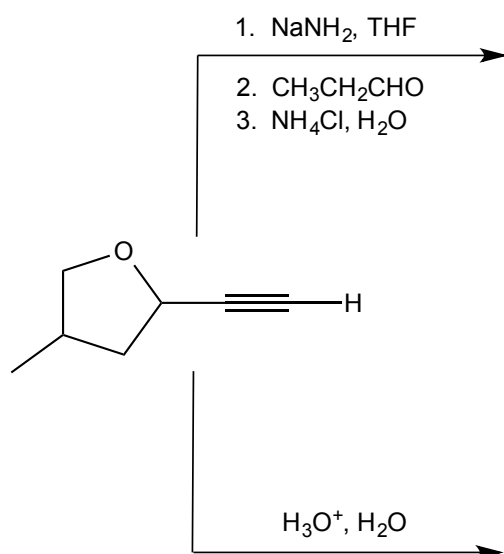


11. Use curved arrows to draw a plausible mechanism for the following reaction.

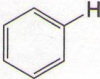

[5 marks]



12. Predict the products formed when the given compound is treated with each of the following. [4 marks]



pK_a values of molecules and ions commonly encountered in organic chemistry.

Acid	Conjugate base	pK _a	Acid	Conjugate base	pK _a
HClO ₄	ClO ₄ ⁻	-10	HCN	CN ⁻	9.2
HI	I ⁻	-9	NH ₄ ⁺	NH ₃	9.2
$\begin{array}{c} \text{+OH} \\ \parallel \\ \text{R}-\text{C}-\text{H} \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{H} \end{array}$	-9	ArOH	ArO ⁻	10
HBr	Br	-9	R-CH ₂ NO ₂	R- $\bar{\text{C}}\text{H}$ -NO ₂	10
H ₂ SO ₄	HSO ₄ ⁻	-7	RNH ₃ ⁺	RNH ₂	11
HCl	Cl ⁻	-7	RSH	RS ⁻	11
$\begin{array}{c} \text{+OH} \\ \parallel \\ \text{R}-\text{C}-\text{R} \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{R} \end{array}$	-7	$\begin{array}{c} \text{O} \quad \text{O} \\ \parallel \quad \parallel \\ \text{CH}_3-\text{C}-\text{C}-\text{OR} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{O} \quad \text{O} \\ \parallel \quad \parallel \\ \text{CH}_3-\text{C}-\text{C}-\text{OR} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	11
ArSO ₃ H	ArSO ₃ ⁻	-6.5	H ₂ O ₂	HOO ⁻	11.6
$\begin{array}{c} \text{+OH} \\ \parallel \\ \text{R}-\text{C}-\text{OR}' \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{OR}' \end{array}$	-6	PhNHCOR	Ph $\bar{\text{N}}$ -COR	13
$\begin{array}{c} \text{H} \\ \\ \text{R}-\text{O}^+-\text{R}' \end{array}$	R-O-R'	-3.5	CH ₃ OH	CH ₃ O ⁻	15.2
$\begin{array}{c} \text{H} \\ \\ \text{R}-\text{O}^+-\text{H} \end{array}$	R-O-H	-2	H ₂ O	HO ⁻	15.7
H ₃ O ⁺	H ₂ O	-1.7	RCH ₂ OH	RCH ₂ O ⁻	16
HNO ₃	NO ₃ ⁻	-1.4	R ₂ CH-OH	R ₂ CH-O ⁻	17
HSO ₄ ⁻	SO ₄ ²⁻	2	R ₃ C-OH	R ₃ C-O ⁻	17
H ₃ PO ₄	H ₂ PO ₄ ⁻	2.1	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{NH}_2 \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{NH}^- \end{array}$	17
HF	F ⁻	3.1	PhCH ₂ COR	Ph $\bar{\text{C}}\text{H}$ -COR	17
HONO	NO ₂ ⁻	3.3	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{CH}_3 \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{R}-\text{C}-\text{CH}_2^- \end{array}$	20
ArNH ₃ ⁺	ArNH ₂	4	$\begin{array}{c} \text{O} \\ \parallel \\ \text{RO}-\text{C}-\text{CH}_3 \end{array}$	$\begin{array}{c} \text{O} \\ \parallel \\ \text{RO}-\text{C}-\text{CH}_2^- \end{array}$	24
HN ₃	N ₃ ⁻	4.6	R-CH ₂ CN	R- $\bar{\text{C}}\text{H}$ -CN	25
RCOOH	RCOO ⁻	5	H-C \equiv C-H	H-C \equiv C ⁻	25
H ₂ CO ₃	HCO ₃ ⁻	6.4	PhNH ₂	PhNH ⁻	28
H ₂ S	HS ⁻	7	H ₂	H ⁻	35
ArSH	ArS ⁻	7	NH ₃	NH ₂ ⁻	38
$\begin{array}{c} \text{O} \quad \text{O} \\ \parallel \quad \parallel \\ \text{CH}_3-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{O} \quad \text{O} \\ \parallel \quad \parallel \\ \text{CH}_3-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array}$	9	Ph-CH ₃	Ph-CH ₂ ⁻	40
					43
			CH ₂ =CH ₂	CH ₂ =CH ⁻	44
			CH ₄	CH ₃ ⁻	48

Abbreviations: Ar = aryl; Ph = phenyl; R = alkyl.

hydrogen 1 H 1.0079																		helium 2 He 4.0026																			
lithium 3 Li 6.941		beryllium 4 Be 9.0122																		boron 5 B 10.811		carbon 6 C 12.011		nitrogen 7 N 14.007		oxygen 8 O 15.999		fluorine 9 F 18.998		neon 10 Ne 20.180							
sodium 11 Na 22.990		magnesium 12 Mg 24.305																		aluminium 13 Al 26.982		silicon 14 Si 28.086		phosphorus 15 P 30.974		sulfur 16 S 32.065		chlorine 17 Cl 35.453		argon 18 Ar 39.948							
potassium 19 K 39.098		calcium 20 Ca 40.078		scandium 21 Sc 44.956		titanium 22 Ti 47.867		vanadium 23 V 50.942		chromium 24 Cr 51.996		manganese 25 Mn 54.938		iron 26 Fe 55.845		cobalt 27 Co 58.933		nickel 28 Ni 58.693		copper 29 Cu 63.546		zinc 30 Zn 65.39		gallium 31 Ga 69.723		germanium 32 Ge 72.61		arsenic 33 As 74.922		selenium 34 Se 78.96		bromine 35 Br 79.904		krypton 36 Kr 83.80			
rubidium 37 Rb 85.468		strontium 38 Sr 87.62		yttrium 39 Y 88.906		zirconium 40 Zr 91.224		niobium 41 Nb 92.906		molybdenum 42 Mo 95.94		technetium 43 Tc [98]		ruthenium 44 Ru 101.07		rhodium 45 Rh 102.91		palladium 46 Pd 106.42		silver 47 Ag 107.87		cadmium 48 Cd 112.41		indium 49 In 114.82		tin 50 Sn 118.71		antimony 51 Sb 121.76		tellurium 52 Te 127.60		iodine 53 I 126.90		xenon 54 Xe 131.29			
caesium 55 Cs 132.91		barium 56 Ba 137.33		57-70 *		lutetium 71 Lu 174.97		hafnium 72 Hf 178.49		tantalum 73 Ta 180.95		tungsten 74 W 183.84		rhenium 75 Re 186.21		osmium 76 Os 190.23		iridium 77 Ir 192.22		platinum 78 Pt 195.08		gold 79 Au 196.97		mercury 80 Hg 200.59		thallium 81 Tl 204.38		lead 82 Pb 207.2		bismuth 83 Bi 208.98		polonium 84 Po [209]		astatine 85 At [210]		radon 86 Rn [222]	
francium 87 Fr [223]		radium 88 Ra [226]		89-102 **		lawrencium 103 Lr [262]		rutherfordium 104 Rf [261]		dubnium 105 Db [262]		seaborgium 106 Sg [266]		bohrium 107 Bh [264]		hassium 108 Hs [269]		meitnerium 109 Mt [268]		ununnillium 110 Uun [271]		unununium 111 Uuu [272]		ununbium 112 Uub [277]		ununquadium 114 Uuq [289]											

Key:

element name
atomic number
symbol
atomic weight (mean relative mass)

*lanthanoids

**actinoids

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]