UNIVERSITY OF CALGARY

FACULTY OF SCIENCE

FINAL EXAMINATION

CHEMISTRY 351

December 11th 2012 Time: 3 Hours

READ ALL THE INSTRUCTIONS CAREFULLY

PLEASE WRITE YOUR NAME, STUDENT I.D. NUMBER ON ***BOTH*** YOUR EXAM ANSWER BOOKLET AND COMPUTER ANSWER SHEET.

The examination consists of Parts 1 - 9, each of which should be attempted. Note that some Parts provide you with a choice of questions, *i.e*. answer 4 out of 5. These will be graded in numerical order until the required number have been completed, regardless of whether they are right or wrong. Parts 1 - 5 will be computer graded, and Parts 6 - 9 are to be answered in the answer booklet provided. A periodic table with atomic numbers and atomic weights, and spectroscopic tables are appended to this examination paper.

Parts 1 - 5 consist of a series of multiple choice questions numbered 1 - 40, which are to be answered on your computer answer sheet. Indicate your answer by blackening out the appropriate space, A, B, C, D or E on the answer sheet. Use a pencil only and ***not ink***. In some cases it is required that you indicate ***multiple*** items for a complete and/or correct answer by blackening out more than one space. In some other cases more than five options are available and some of these also require more than one space to be blackened out. For an example, an option specified as AB requires that you blacken out ***both*** space A and space B. Part marks may be awarded in some of the questions. Incorrect answers must be erased ***cleanly***.

Molecular models are permitted during the exam; calculators are also permitted, ***but NOT programmable calculators***.

Absolutely no other electronic devices are allowed

15% PART 1: RELATIVE PROPERTIES

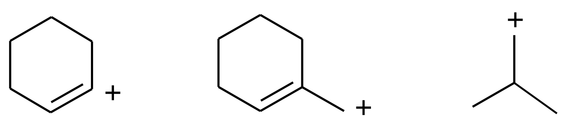
ANSWER ANY TEN (10) OF QUESTIONS 1 TO 12.

Arrange the items in questions 1-12 in DECREASING ORDER (i.e. greatest, most etc. first) with respect to the indicated property.

Use the following code to indicate your answers.

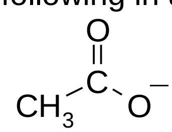
A.	**i** > **ii** > **iii**	**D**.	**ii** > **iii** > **i**
B.	**i** > **iii** > **ii**	**E**.	**iii** > **i** > **ii**
C.	**ii** > **i** > **iii**	**AB**.	**iii** > **ii** > **i**

1. The relative stability of the following carbocations:



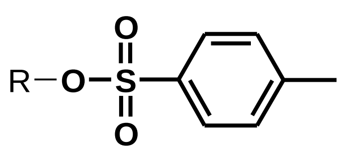
i **ii** **iii**

2. The relative nucleophilicity of the following in a polar, protic solvent:

$CH_3CH_2S^-$  CH_3CH_2OH

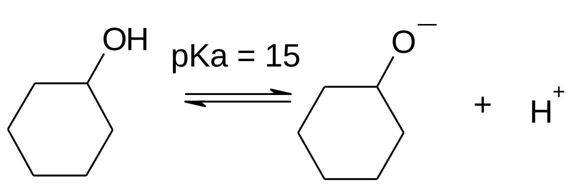
i **ii** **iii**

3. The relative leaving group ability of the **bold group** in each of the following:

 R—**Br** R—**OH**

i **ii** **iii**

4. The relative amount of the conjugate base of cyclohexanol formed by the reaction of 1 mole equivalent of each of the following:



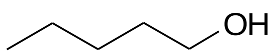
H_2O $CH_3CH_2O^-$ NH_2^-

i **ii** **iii**

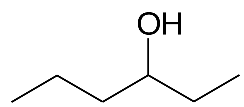
Use the following code to indicate your answers.

A.	**i** > **ii** > **iii**	**D.**	**ii** > **iii** > **i**
B.	**i** > **iii** > **ii**	**E.**	**iii** > **i** > **ii**
C.	**ii** > **i** > **iii**	**AB.**	**iii** > **ii** > **i**

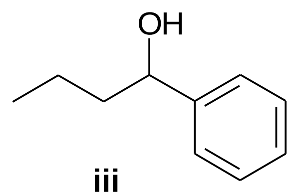
5. The relative rate of reaction of each of the following when treated with HBr:



i



ii

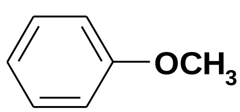


iii

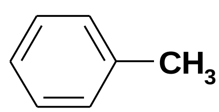
6. The relative rate of reaction of each of the following with $AgNO_3$ / aq. ethanol :

i 2-Bromopropane
ii 1-Bromopropane
iii Benzyl bromide

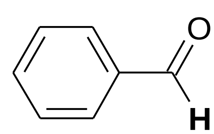
7. The [1]H-NMR chemical shifts for the groups shown in **bold** in each of the following structures:



i

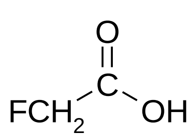


ii

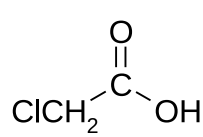


iii

8. The relative acidity of each of the following:



i



ii

CH_3CH_2SH

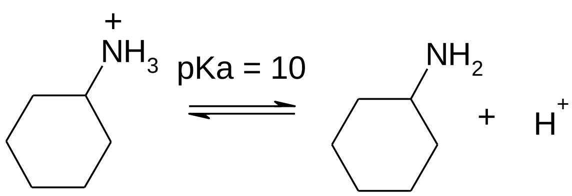
iii

Cont'd -->

Use the following code to indicate your answers.

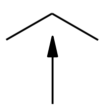
A.	**i** > **ii** > **iii**	**D.**	**ii** > **iii** > **i**
B.	**i** > **iii** > **ii**	**E.**	**iii** > **i** > **ii**
C.	**ii** > **i** > **iii**	**AB.**	**iii** > **ii** > **i**

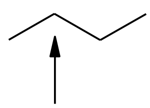
9. The relative amount of the conjugate acid of cyclohexylamine formed by the reaction of 1 mole equivalent of each of the following:

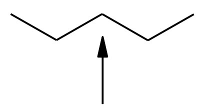


H_2SO_4	H_3O+	CH_3CO_2H
i	**ii**	**iii**

10. The number of lines in the H-NMR signals for the H atoms at the positions indicated in each of the following :


i

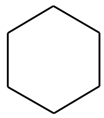

ii

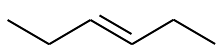

iii

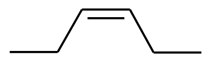
11. The relative yields of the anti-Zaitsev product (also known as the Hoffman product) produced by the reaction of 2-bromo-2,3-dimethylbutane with each of the following:

$NaOCH_2CH_3$	$NaOCH_3$	$NaOC(CH_3)_3$
i	**ii**	**iii**

12. The relative heats of combustion of the following isomers (least exothermic to most exothermic):


i


ii

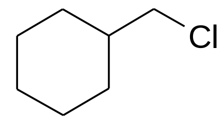

iii

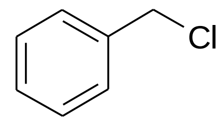
10% PART 2: MOLECULAR PROPERTIES

ANSWER ANY FIVE (5) OF THE QUESTIONS 13 TO 18.

CHOOSE THE SINGLE OPTION THAT PROVIDES THE BEST ANSWER.

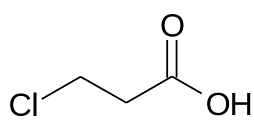
13. Which of the following is more reactive under SN1 conditions ?

I


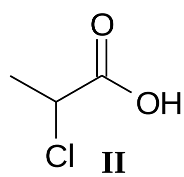
II


- **A.** **I** because it forms a less stable primary carbocation
- **B.** **II** because it forms a less stable primary carbocation
- **C.** **I** because it is less sterically hindered
- **D.** **II** because it is less sterically hindered
- **E.** **II** because it forms a resonance stabilized carbocation

14. Which of the following is the strongest acid ?



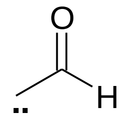
I



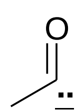
II

- **A.** **I** because there is less of a steric effect due to the large Cl atom
- **B.** **II** because there is a greater steric effect due to the large Cl atom
- **C.** **I** because of the greater inductive effect of the more distant Cl atom
- **D.** **II** because of the greater inductive effect of the closer Cl atom
- **E.** There is no difference because both are carboxylic acids

15. Which of the following is the conjugate base of ethanal ?



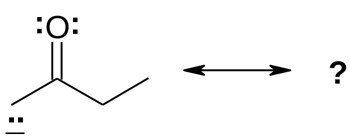
I



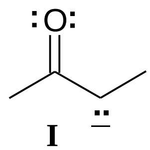
II

- **A.** **I** because the –ve charge can be delocalised
- **B.** **II** because the –ve charge can be delocalised
- **C.** **I** because the negative charge is further from the electronegative oxygen
- **D.** **II** because the negative charge is closer to the more electronegative oxygen
- **E.** **II** because it has the lower pKa

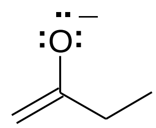
16. Which of the following is/are resonance structures of the structure **X** ?



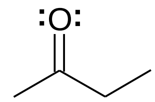
X



I



II



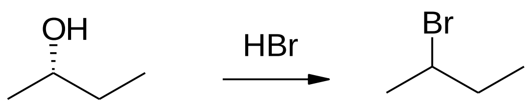
III

A. None of **I**, **II** or **III** are resonance structures of **X**

B. **I** only **C.** **II** only **D**. **III** only **E**. **I** and **II** only

AB. All of **I**, **II** and **III** are resonance structures of **X**

17. In the following reaction, stereochemistry:



A. Is lost because the reaction is SN1 and takes place with inversion

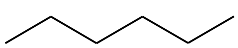
B. Is reversed because the reaction is SN2 and takes place with inversion.

C. Is lost because the reaction is SN1 and occurs via a carbocation intermediate.

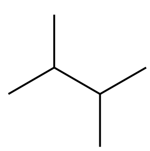
D. Is lost because the reaction is neither SN1 nor SN2

E. Is irrelevant because the alcohol does not have a chirality center

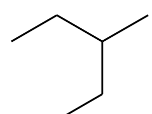
18. Which of the following isomers has the highest boiling point ?



I



II



III

A. **I** because it is the most thermodynamically stable

B. **II** because it is the most thermodynamically stable

C. **III** because it is the most thermodynamically stable

D. **I** because it has more surface area

E. **II** because it is more branched

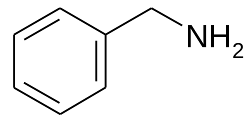
14% PART 3: REACTIONS

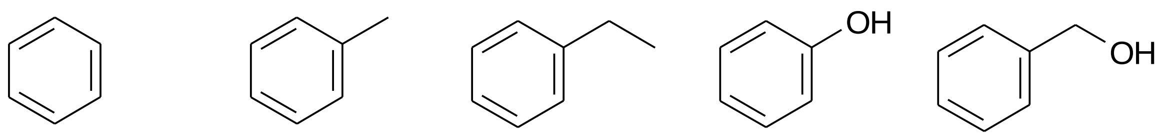
ANSWER ANY SEVEN (7) OF QUESTIONS 19 TO 26.

For each of questions 19-26 select the MISSING component (the best starting material, the major product or the best reagents) required in order to BEST complete each of the reaction schemes.

19.

? —— 1. Br_2 / uv; 2. excess NH_3 ——→

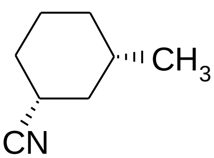


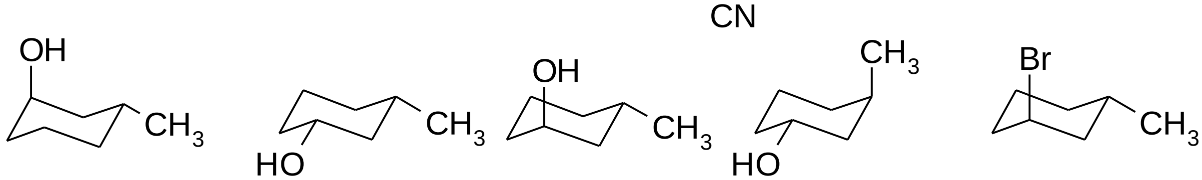


A **B** **C** **D** **E**

20.

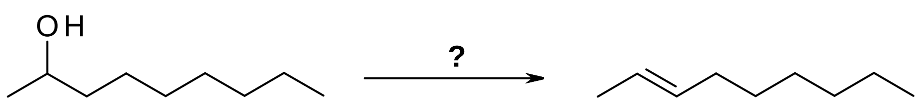
? —— 1. TsCl, pyridine; 2. NaCN / DMSO ——→





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

21.



A conc. H_2SO_4 / heat

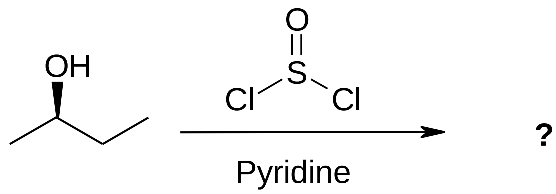
B HBr / heat

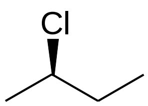
C NaOH / heat

D 1. H_2O / H_2SO_4
2. NaOH / heat

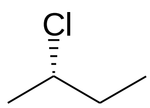
E 1. PBr_3 / $N(CH_2CH_3)_3$
2. KO^tBu / heat

22.

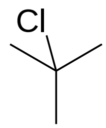




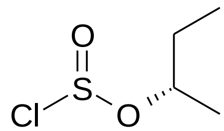
A



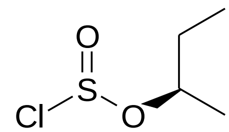
B



C

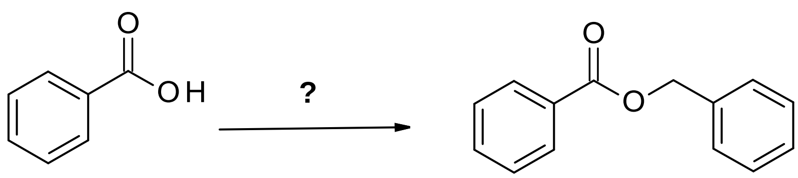


D



E

23.



A Phenol / Pyridine

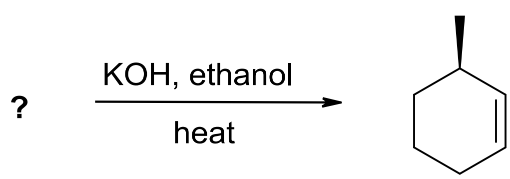
B Benzyl alcohol / Pyridine

C Benzyl chloride / Pyridine

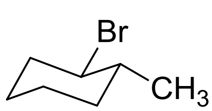
D 1. PBr_3 / $N(CH_2CH_3)_3$
2. Phenol / Pyridine

E 1. TsOH / $N(CH_2CH_3)_3$
2. Chlorobenzene / Pyridine

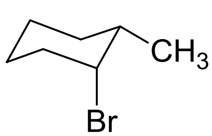
24.



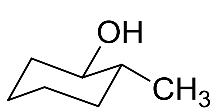
Only Product



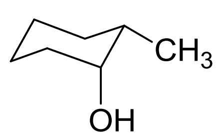
A



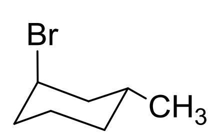
B



C

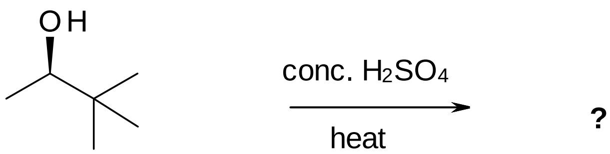


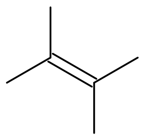
D



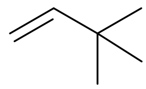
E

25.

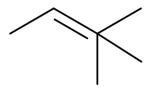




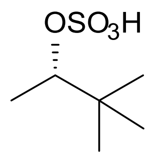
A



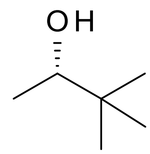
B



C

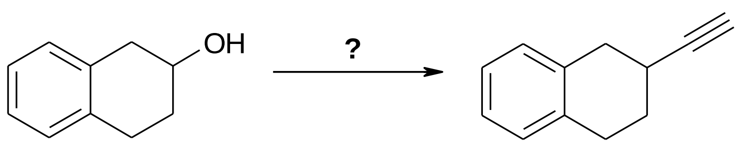


D



E

26.



A HC≡CH / $NaNH_2$

B 1. HBr
2. HC≡CNa

C 1. H_2SO_4 / heat
2. Br_2
3. HC≡CNa

D HC≡CNa

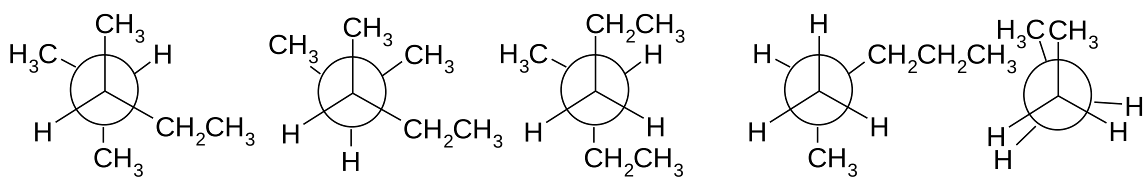
E 1. $SOCl_2$ / NEt_3
2. HC≡CNa

12% PART 4: CONFORMATIONAL ANALYSIS

ANSWER SIX (6) OF THE QUESTIONS 27 TO 34.

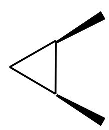
For each of the questions 27-34 select the answer(s) from those provided. In some cases more than one answer may be correct in which case all correct answers should be selected for full marks.

27. Which of the Newman projections shown represent conformations of 2-methylpentane ?



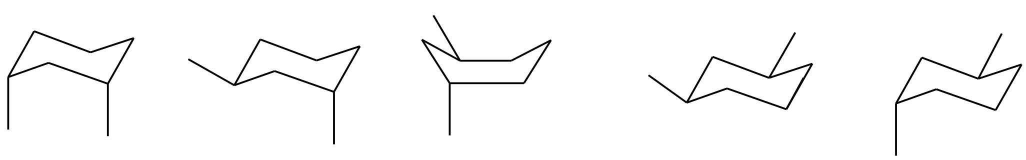
A **B** **C** **D** **E**

28. What is the **torsional** angle between the two methyl groups in the most stable conformation of the substituted cyclopropane shown below ?



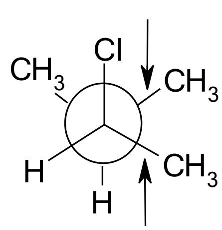
A 0°
B 60°
C 90°
D 109.5°
E 120°
AB 180°

29. Which of the following structures represent conformations that can be adopted by *cis*-1,3-dimethylcyclohexane ? (Indicate **all that apply)**



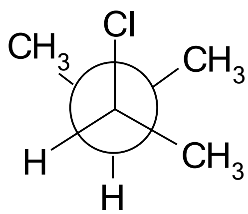
A **B** **C** **D** **E**

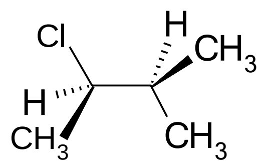
30. Which of the following terms **best** describes the relative position of the two indicated bonds in the conformation of the molecule shown below?



A eclipsed
B staggered
C anti
D syn
E gauche
AB trans
AC cis

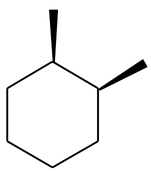
31. Which of the following terms **best** describes the relationship between the two molecules shown below ?





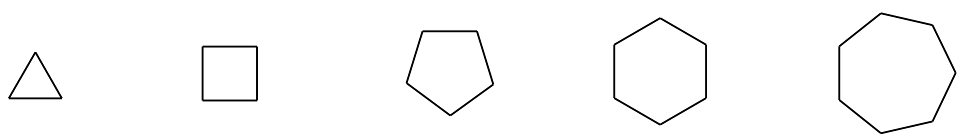
A constitutional isomers
B identical
C conformational isomers
D enantiomers
E diastereomers
AB meso
AC not isomers

32. What term(s) associated with types of strain can be used to describe the molecule shown below in its most stable conformation ?



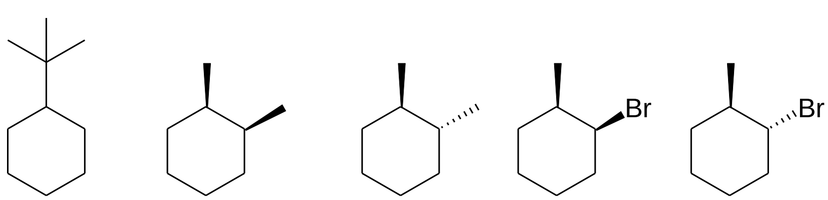
A Van der Waals
B torsional (eclipsing)
C 1,3-diaxial
D flagpole
E ring

33. Which of the following molecules would have the least exothermic heat of combustion per methylene (-CH_2-) unit ?



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

34. Which of the following structures have two chair conformations of equal energy



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

Cont'd -->

12% PART 5: SPECTROSCOPY

ANSWER ALL SIX (6) OF QUESTIONS 35 TO 40.

For each of questions 37-42 select the compound from the list provided that corresponds BEST with the spectroscopic data provided. The following common abbreviations have been used s = singlet, d = doublet, t = triplet, q = quartet, p= pentet, m = multiplet.

35. **^{1}H NMR** : δ/ppm 1.0 (t, 3 H), 1.6 (sextet, 2 H), 2.0 (s, 3 H), 4.1 (t, 2 H).
^{13}C-NMR: δ/ppm 10.4, 20.9, 22.1, 66.1, 171
IR = 1745 cm^{-1}

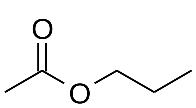
36. **^{1}H-NMR**: δ/ppm 1.22 (t, 3H), 2.64 (q, 2H) 7.14 (m, 2H)
^{13}C-NMR: δ/ppm 15.4, 25.5, 126, 128.3, 141.6
IR: 1489, 1461 cm^{-1}

37. **^{1}H-NMR**: δ/ppm 1.0 (t, 3H), 2.4 (q, 2H)
^{13}C-NMR: δ/ppm 7.9, 35.5, 212
IR: 1720 cm^{-1}

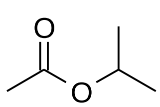
38. **^{1}H-NMR**: δ/ppm 0.9 (t, 3H), 1.2 (d, 3H), 1.32-1.48 (m, 4H), 2.6 (s, 1H, D_2O exchange), 3.8 (sextet, 1H)
^{13}C-NMR: δ/ppm 14.1, 19.0, 23.4, 41.6, 67.7
IR: 3100-3500 cm^{-1}

39. **^{1}H-NMR**: δ/ppm 0.9 (t, 3H), 1.5 (sextet, 2H), 2.0 (t, 2H), 6.7 (s, 1H), 7.2 (s, 1H)
^{13}C-NMR: δ/ppm 13.7, 19.0, 37.9, 176.4
IR: 3356, 3184, 1660 cm^{-1}

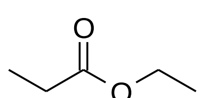
40. **^{1}H-NMR**: δ/ppm 1.0 (t, 3H), 1.7 (sextet, 2H), 2.3 (t, 2H), 11.5 (s, 1H, D_2O exchange)
^{13}C-NMR: δ/ppm 13.7, 18.4, 36.2, 180.7
IR: 2700-3300, 1712 cm^{-1}



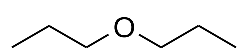
A



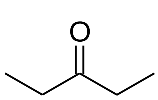
B



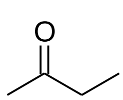
C



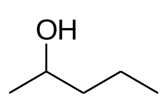
D



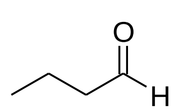
E



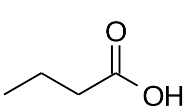
AB



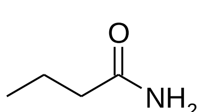
AC



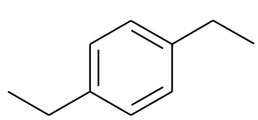
AD



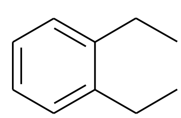
AE



BC



BD



BE

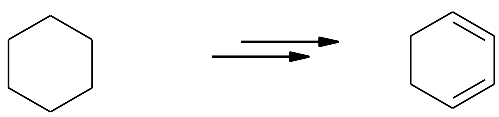
8% PART 6: SYNTHESIS

DESIGN EFFICIENT SYNTHESES OF ANY TWO (2) of the following target molecules from the indicated starting materials. In addition, you are allowed to use any hydrocarbon with three or fewer carbon atoms, any solvents or inorganic reagents, and any organic reagents that do not contribute carbon atoms to the carbon skeleton in the product. More than one step will be required for each synthesis. Clearly show the required reagents and the product of each step.

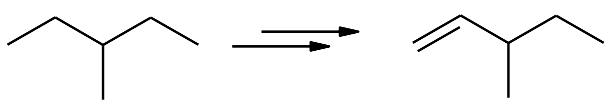
WRITE YOUR ANSWERS IN THE EXAM BOOKLET PROVIDED.

DO NOT SHOW MECHANISMS.

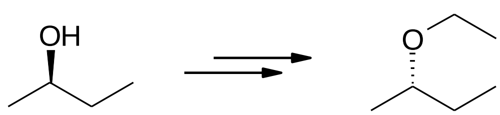
A.



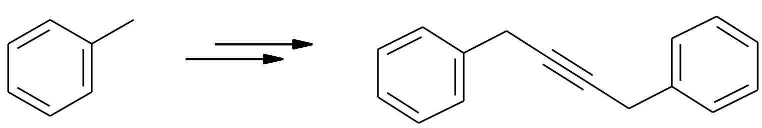
B.



C.



D.

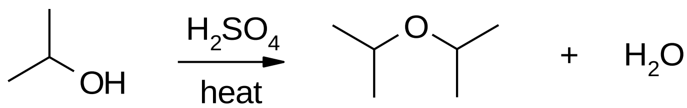


9% PART 7: MECHANISMS

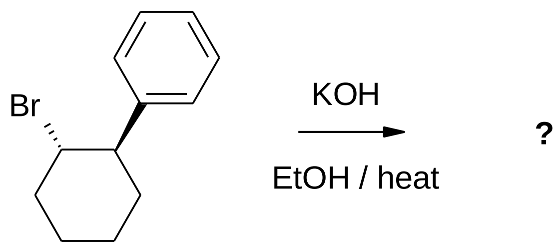
WRITE YOUR ANSWERS IN THE BOOKLET PROVIDED

Use curly arrows to show the mechanism in order to explain **ANY TWO** of the following:

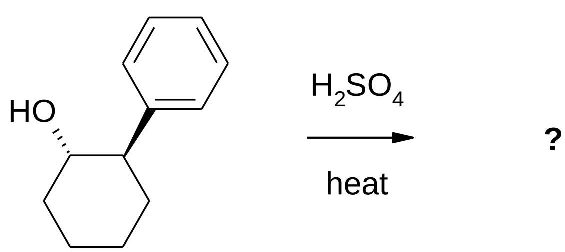
A Draw the reaction mechanism for the reaction of propan-2-ol to give diisopropyl ether.



B Predict the major product of this reaction by showing the mechanism. Briefly justify your choice.



C Predict the major product of this reaction by showing the mechanism. Briefly justify your choice.

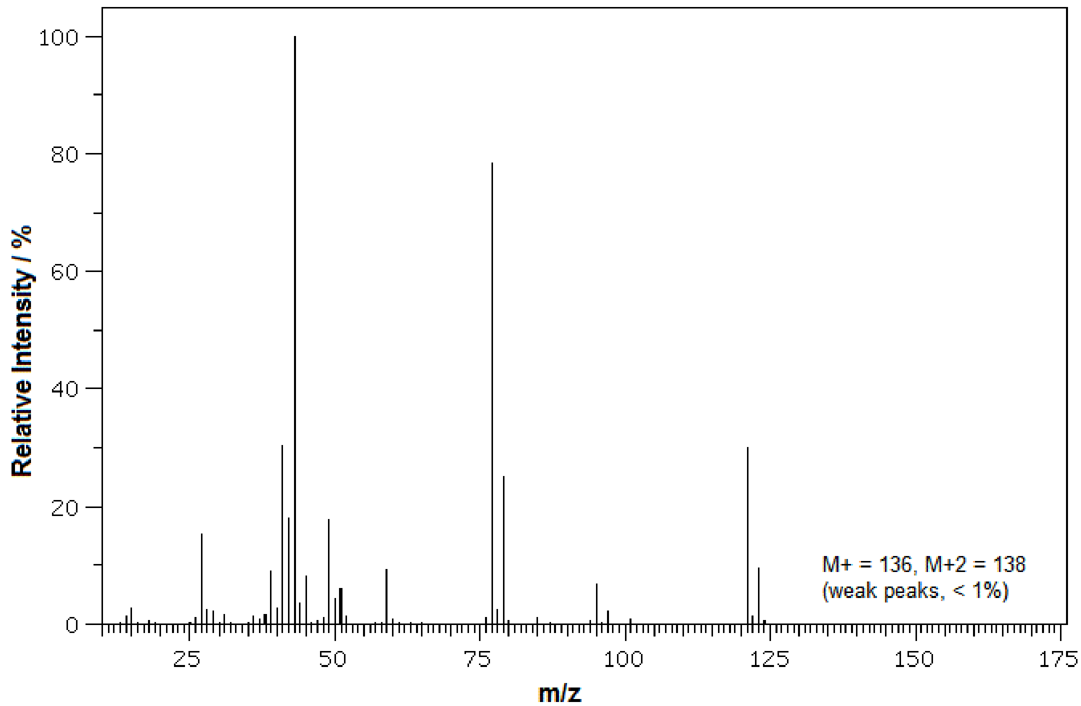


10% PART 8: SPECTROSCOPY

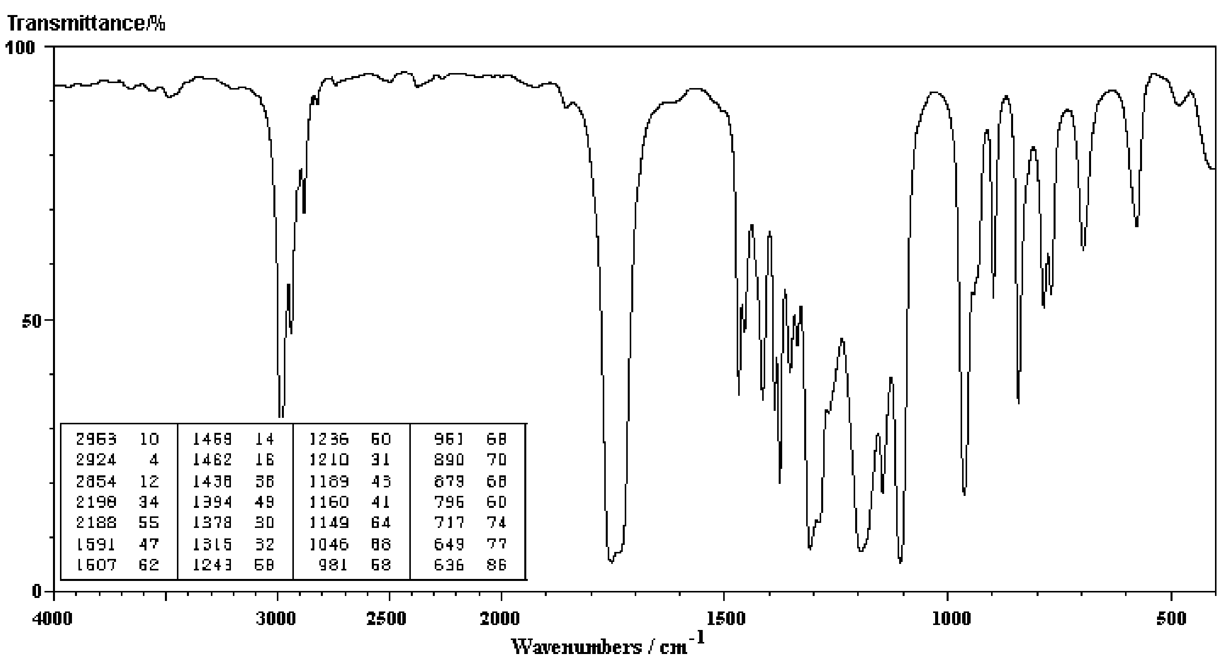
WRITE YOUR ANSWERS IN THE BOOKLET PROVIDED. Show your workings as PARTIAL marks will be given.

From the spectral data provided below, identify the structure of the "unknown" molecule.

Mass Spectrum:

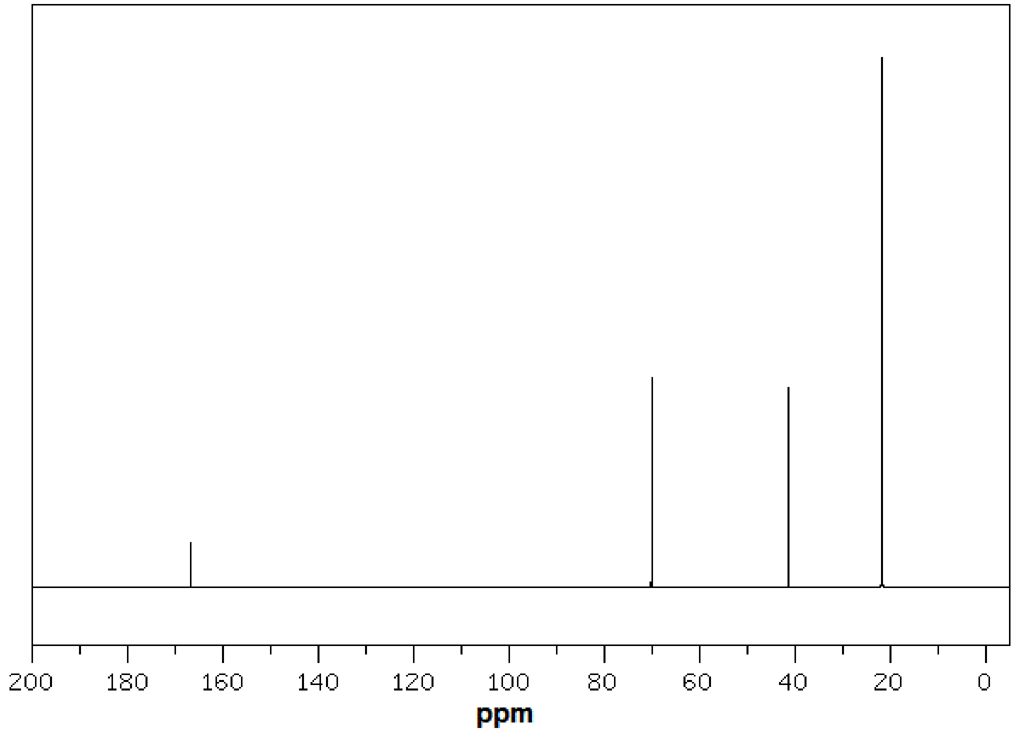


IR Spectrum:

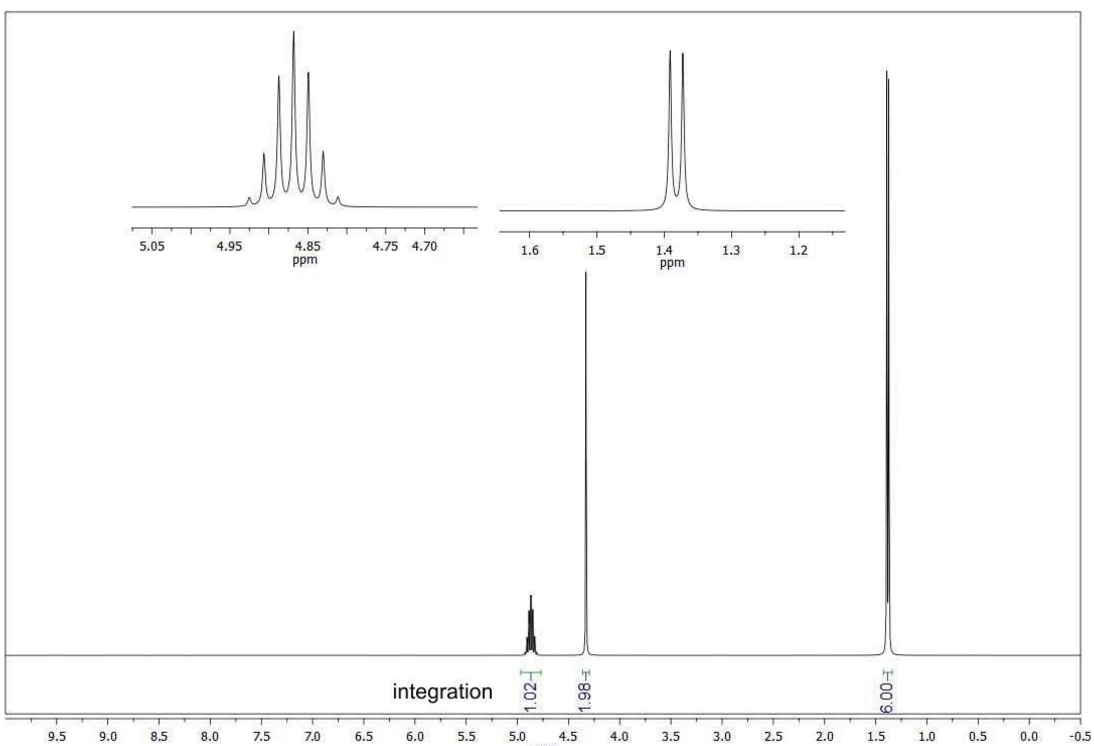


2963	10	1469	14	1236	60	961	68
2924	4	1462	16	1210	31	890	70
2854	12	1438	38	1169	43	879	68
2198	34	1394	49	1160	41	796	60
2188	55	1378	30	1149	64	717	74
1591	47	1315	32	1046	88	649	77
1607	62	1243	68	981	68	636	86

^{13}C-NMR:



^{1}H-NMR:



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10% PART 9: STRUCTURE DETERMINATION

WRITE YOUR ANSWERS IN THE BOOKLET PROVIDED

A chiral alkyl bromide, **A** $C_6H_{13}Br$ was determined to have an R configuration**.** **A** was observed to react at a moderate rate with either aqueous ethanolic silver nitrate or with sodium iodide in acetone. When **A** was reacted with either KOH / heat or KOtBu / DMSO / heat it gave the same product, **B**, C_6H_{12} (IR: 1650cm^{-1}). The H NMR of **B** showed the following peaks: 1.2 ppm, 9H, singlet; 5.0 ppm, 2H multiplet; 5.7 ppm, 1H, doublet of doublets; The normal ^{13}C NMR of **B** had 4 peaks.

When **A** was reacted with cold NaOH solution the major product was a chiral compound **C**, $C_6H_{14}O$ (IR: 3500cm^{-1}, broad).

When **C** was reacted with PBr_3 / Et_3N, **A** was obtained but when **C** was treated with HBr the reaction gave an achiral product, **D** as the major product. **D** was observed to react rapidly with aqueous ethanolic silver nitrate but very slowly (if at all) with sodium iodide in acetone. **D** was found to be a constitutional isomer of **A**. **D** could also be obtained on reaction of 2,3-dimethylbutane with bromine / uv light.

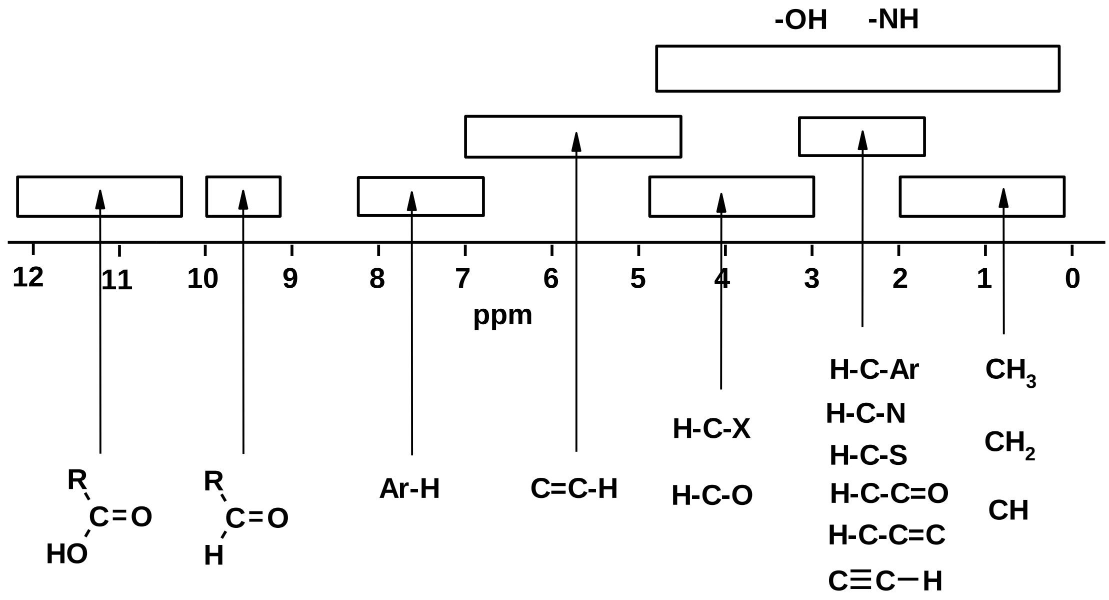
When **C** was heated with conc. H_2SO_4, the major product was **E**, a constitutional isomer of **B**. The normal ^{13}C NMR spectrum of **E** had only 2 peaks. **E** was also formed as the major product of the reaction of **D** with hot ethanolic KOH.

- **Identify A-E (only structures are needed)**
- **Draw a structure showing the stereochemistry and give the complete name of one enantiomer of C.**

****** THE END ******

SPECTROSCOPIC TABLES

^{1}H NMR

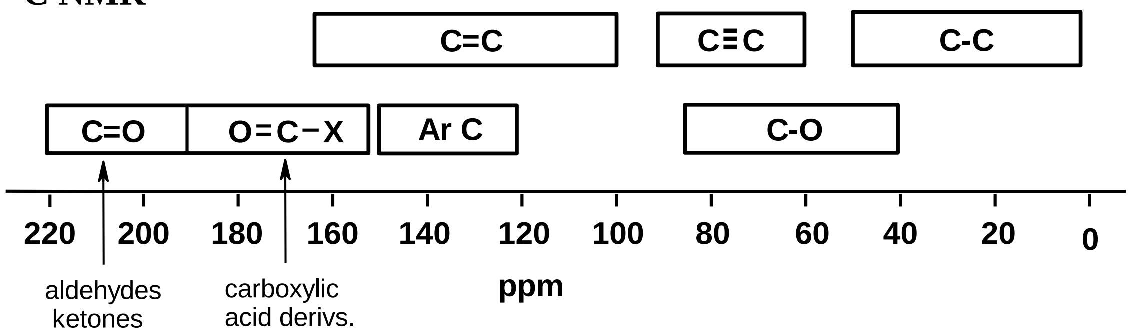


^{1}H NMR CHARACTERISTIC CHEMICAL SHIFTS / ppm

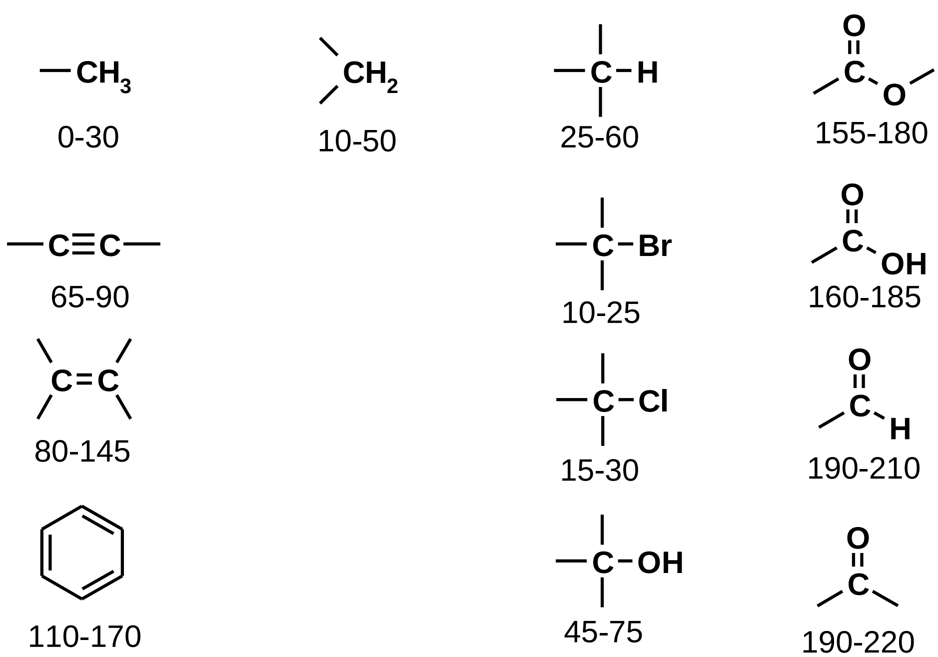
	methyl CH_3-	methylene $-CH_2$-	methyne CH	other	
R−C−	0.9	1.4	1.5	-OH	1-5
				-NH	1-3
R-C=C	1.6	2.3	2.6	C≡CH	2.5
				C=C-H	5.5
R-C(=O)-	2.1	2.4	2.5	Ar-H	7.3
R−N<	2.2	2.5	2.9	R-C(=O)-H	10
R-Ar	2.3	2.7	3.0	R-C(=O)-OH	9-12
R−Br	2.7	3.3	4.1		
R−Cl	3.1	3.4	4.1		
R−O−	3.3	3.4	3.7		

Cont'd -->

^{13}C NMR



^{13}C NMR CHARACTERISTIC CHEMICAL SHIFTS / ppm



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INFRA-RED GROUP ABSORPTION FREQUENCIES

		TYPE OF VIBRATION	FREQUENCY (cm^{-1})	WAVELENGTH (μ)	INTENSITY (1)
C–H	Alkanes	(stretch)	3000-2850	3.33-3.51	s
	–CH_3	(bend)	1450 and 1375	6.90 and 7.27	m
	–CH_2–	(bend)	1465	6.83	m
	Alkenes	(stretch)	3100-3000	3.23-3.33	m
		(bend)	1700-1000	5.88-10.0	s
	Aromatics	(stretch)	3150-3050	3.17-3.28	s
		(out-of-plane bend)	1000-700	10.0-14.3	s
	Alkyne	(stretch)	ca. 3300	ca.3.03	s
	Aldehyde		2900-2800	3.45-3.57	w
			2800-2700	3.57-3.70	w
C–C	Alkane	not usually useful			
C=C	Alkene		1680-1600	5.95-6.25	m-w
	Aromatic		1600-1400	6.25-7.14	m-w
C≡C	Alkyne		2250-2100	4.44-4.76	m-w
C=O	Aldehyde		1740-1720	5.75-5.81	s
	Ketone		1725-1705	5.80-5.87	s
	Carboxylic acid		1725-1700	5.80-5.88	s
	Ester		1750-1730	5.71-5.78	s
	Amide		1700-1640	5.88-6.10	s
	Anhydride		ca. 1810	ca. 5.52	s
			ca. 1760	ca. 5.68	s
	Acyl chloride		1800	5.55	s
C–O	Alcohols, Ethers, Esters,				
	Carboxylic acids		1300-1000	7.69-10.0	s
O–H	Alcohols, Phenols				
	Free		3650-3600	2.74-2.78	m
	H-Bonded		3400-3200	2.94-3.12	m
	Carboxylic acids (2)		3300-2500	3.03-4.00	m
N–H	Primary and secondary amines		ca. 3500	ca. 2.86	m
C≡N	Nitriles		2260-2240	4.42-4.46	m
N=O	Nitro (R–NO_2)		1600-1500	6.25-6.67	s
			1400-1300	7.14-7.69	s
C–X	Fluoride		1400-1000	7.14-10.0	s
	Chloride		800-600	12.5-16.7	s
	Bromide, Iodide		<600	>16.7	s

(1) s = strong, m = medium and w = weak

(2) note that the -OH absorption of solid carboxylic acids which run as a nujol mull can be difficult to see as they maybe very broad

Cont'd -->

PERIODIC TABLE

1 1A	**2** 2A	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13** 3A	**14** 4A	**15** 5A	**16** 6A	**17** 7A	**18** 8A
1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57* **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.0	89** **Ac** (227)	104 **Rf** (261)	105 **Ha** (262)	106 **Sg** (263)	107 **Ns** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Uun** (269)	111 **Uuu** (272)							

Lanthanides *	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
Actinides **	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)