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Chemistry
Higher level
Paper 1

Wednesday 13 November 2019 (afternoon)

1 hour

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.
- The maximum mark for this examination paper is **[40 marks]**.

The Periodic Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18					
1	1 H 1.01	<table border="1"> <tr> <td>Atomic number</td> </tr> <tr> <td>Element</td> </tr> <tr> <td>Relative atomic mass</td> </tr> </table>																	Atomic number	Element	Relative atomic mass	2 He 4.00	
Atomic number																							
Element																							
Relative atomic mass																							
2	3 Li 6.94	4 Be 9.01																		9 F 19.00	10 Ne 20.18		
3	11 Na 22.99	12 Mg 24.31																		17 Cl 35.45	18 Ar 39.95		
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	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 72.63	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.90					
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29					
6	55 Cs 132.91	56 Ba 137.33	57 † La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)					
7	87 Fr (223)	88 Ra (226)	89 † Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (269)	109 Mt (278)	110 Ds (281)	111 Rg (281)	112 Cn (285)	113 Unt (286)	114 Uug (289)	115 Uup (288)	116 Uuh (293)	117 Uus (294)	118 Uuo (294)					
																		†	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
																		‡	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

1. 0.10 mol of hydrochloric acid is mixed with 0.10 mol of calcium carbonate.



Which is correct?

	Limiting reagent	Maximum yield of CO_2 / mol
A.	HCl(aq)	0.10
B.	$\text{CaCO}_3(\text{s})$	0.05
C.	HCl(aq)	0.05
D.	$\text{CaCO}_3(\text{s})$	0.10

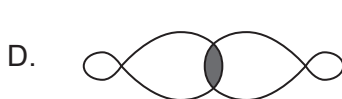
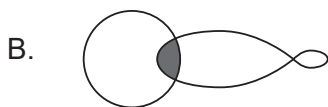
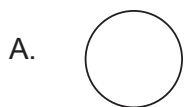
2. What is the sum of the coefficients when the equation is balanced with whole numbers?



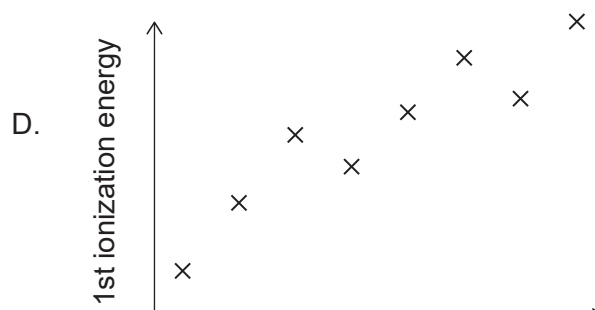
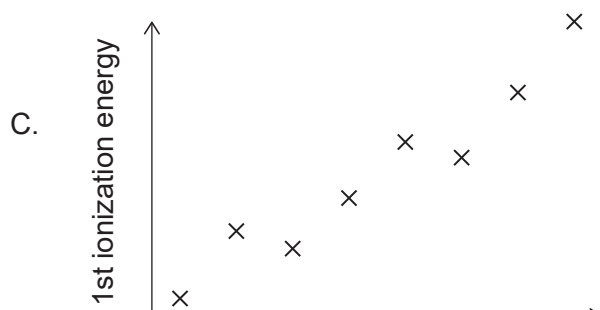
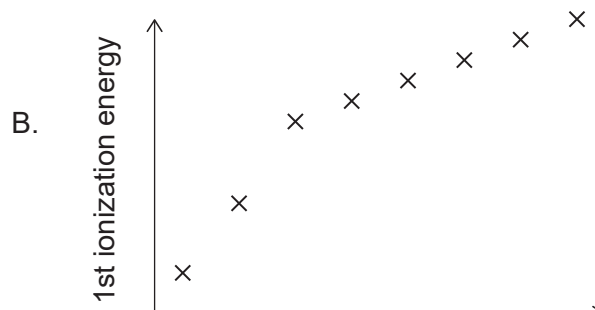
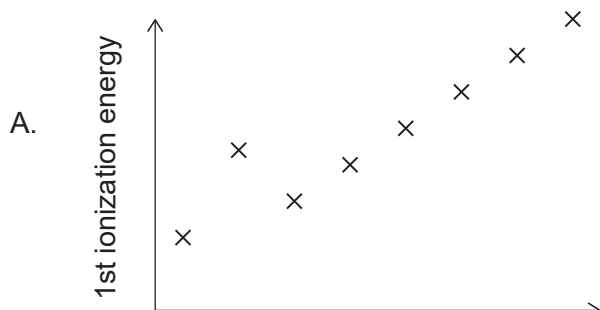
- A. 6
 B. 7
 C. 8
 D. 9
3. Which contains the greatest number of moles of oxygen atoms?

- A. 0.05 mol $\text{Mg}(\text{NO}_3)_2$
 B. 0.05 mol $\text{C}_6\text{H}_4(\text{NO}_2)_2$
 C. 0.1 mol H_2O
 D. 0.1 mol NO_2

4. Which represents the shape of an s atomic orbital?



5. Which shows the first ionization energies of successive elements across period 2, from left to right?



6. Which property shows a general increase from left to right across period 2, Li to F?

- A. Melting point
- B. Electronegativity
- C. Ionic radius
- D. Electrical conductivity

7. Which is an f-block element?

- A. Sc
- B. Sm
- C. Sn
- D. Sr

8. What is the effect of a stronger ligand?

	d-d splitting	Wavelength absorbed
A.	increases	decreases
B.	decreases	decreases
C.	increases	increases
D.	decreases	increases

9. Which compound has the shortest C to O bond?

- A. CH_3CHO
- B. CO
- C. CO_2
- D. $\text{C}_2\text{H}_5\text{OC}_2\text{H}_5$

10. Which describes a resonance structure?

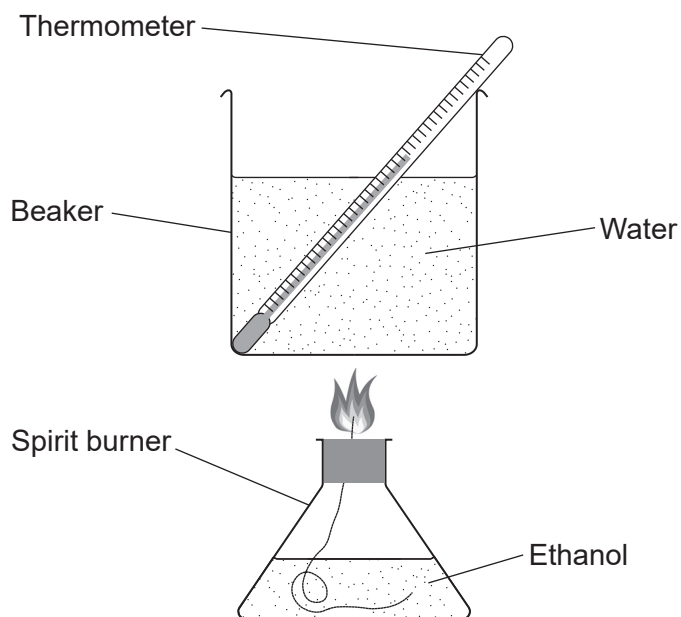
- A. Double bond can be drawn in alternative positions.
- B. Bonds vibrate by absorbing IR radiation.
- C. A double and a single bond in the molecule
- D. A Lewis structure

11. What is the structure and bonding in $\text{SiO}_2(\text{s})$?

	Structure	Bonding
A.	giant	covalent
B.	giant	ionic
C.	bent molecule	covalent
D.	linear molecule	covalent

12. Which atom is sp^2 hybridized?
- A. C in H_2CO
 - B. C in CO_2
 - C. N in CH_3NH_2
 - D. O in H_2O
13. Which atom does **not** obey the octet rule?
- A. C in CO_2
 - B. F in BF_3
 - C. O in H_2O
 - D. S in SF_6

Questions 14 and 15 are about an experiment to measure the enthalpy of combustion, ΔH_c , of ethanol, using the apparatus and setup shown.



14. What is the enthalpy of combustion, ΔH_c , of ethanol in kJ mol^{-1} ?

Maximum temperature of water: 30.0°C

Initial temperature of water: 20.0°C

Mass of water in beaker: 100.0 g

Loss in mass of ethanol: 0.230 g

M_r (ethanol): 46.08

Specific heat capacity of water: $4.18 \text{ J g}^{-1} \text{ K}^{-1}$

$q = mc\Delta T$

A.
$$-\frac{100.0 \times 4.18 \times (10.0 + 273)}{\frac{0.230}{46.08} \times 1000}$$

B.
$$-\frac{0.230 \times 4.18 \times 10.0}{\frac{100.0}{46.08} \times 1000}$$

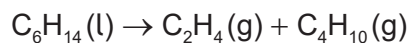
C.
$$-\frac{100.0 \times 4.18 \times 10.0}{\frac{0.230}{46.08} \times 1000}$$

D.
$$-\frac{100.0 \times 4.18 \times 10.0}{\frac{0.230}{46.08}}$$

15. Which quantity is likely to be the most inaccurate due to the sources of error in this experiment?

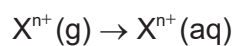
- A. Mass of ethanol burnt
- B. Molecular mass of ethanol
- C. Mass of water
- D. Temperature change

16. What is the enthalpy change of the reaction?



	Enthalpy of combustion / kJ mol^{-1}
$\text{C}_6\text{H}_{14}(\text{l})$	-4163
$\text{C}_2\text{H}_4(\text{g})$	-1411
$\text{C}_4\text{H}_{10}(\text{g})$	-2878

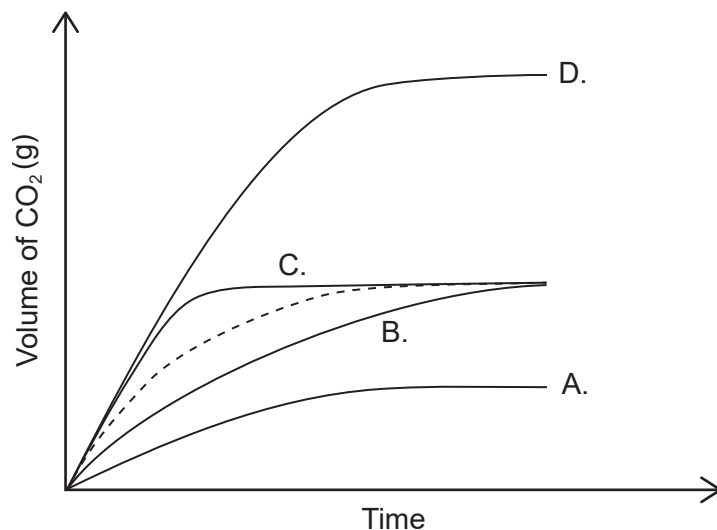
- A. + 1411 + 2878 + 4163
- B. + 1411 - 2878 - 4163
- C. + 1411 + 2878 - 4163
- D. - 1411 - 2878 + 4163
17. Which reaction has the greatest increase in entropy of the system?
- A. $\text{HCl}(\text{g}) + \text{NH}_3(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{s})$
- B. $(\text{NH}_4)_2\text{Cr}_2\text{O}_7(\text{s}) \rightarrow \text{Cr}_2\text{O}_3(\text{s}) + \text{N}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$
- C. $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- D. $\text{I}_2(\text{g}) \rightarrow \text{I}_2(\text{s})$
18. What is the order of increasing (more exothermic) enthalpy of hydration?



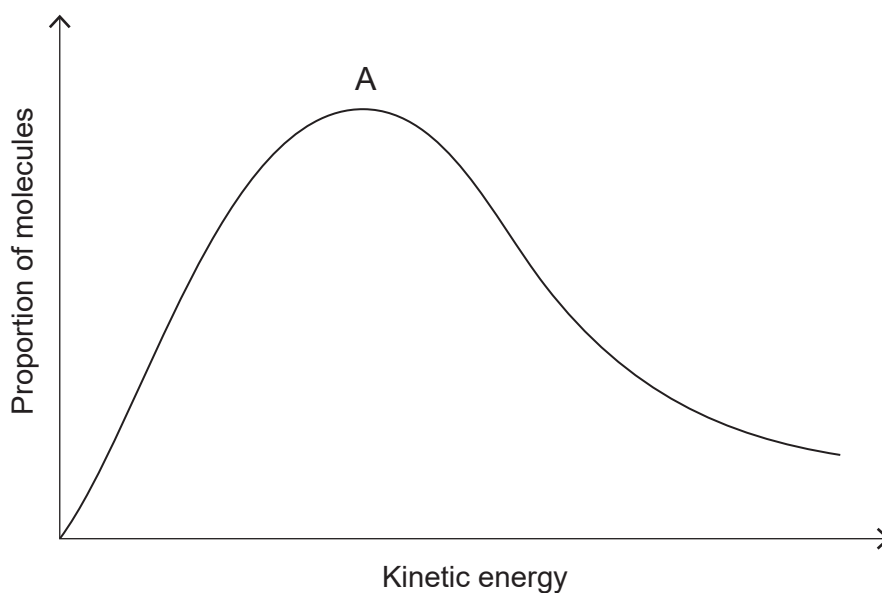
- A. Ca^{2+} , Mg^{2+} , K^+ , Na^+
- B. Na^+ , K^+ , Mg^{2+} , Ca^{2+}
- C. K^+ , Na^+ , Ca^{2+} , Mg^{2+}
- D. Mg^{2+} , Ca^{2+} , Na^+ , K^+

19. The dotted line represents the volume of carbon dioxide evolved when excess calcium carbonate is added to hydrochloric acid.

Which graph represents the production of carbon dioxide when excess calcium carbonate is added to the same volume of hydrochloric acid of double concentration?



20. The graph shows the Maxwell-Boltzmann energy distribution curve for a given gas at a certain temperature.



How will the curve change if the temperature of the gas is increased, while other conditions remain constant?

- A. The maximum is higher and to the left of A.
- B. The maximum is higher and to the right of A.
- C. The maximum is lower and to the right of A.
- D. The maximum is lower and to the left of A.

21. Which is correct?

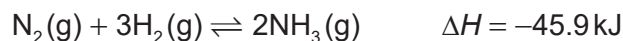
	Units of second-order rate constant	Effect of increasing temperature on rate constant
A.	$\text{mol dm}^{-3} \text{s}^{-1}$	increases
B.	$\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$	increases
C.	$\text{mol dm}^{-3} \text{s}^{-1}$	no change
D.	$\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$	no change

22. What is the intercept on the y -axis when a graph of $\ln k$ is plotted against $\frac{1}{T}$ on the x -axis?

$$\ln k = -\frac{E_a}{RT} + \ln A$$

- A. $\ln A$
- B. $-\frac{E_a}{R}$
- C. $\frac{R}{E_a}$
- D. E_a

23. What effect does increasing both pressure and temperature have on the equilibrium constant, K_c ?



- A. Decreases
- B. Increases
- C. Remains constant
- D. Cannot be predicted as effects are opposite

24. Which corresponds to a system at equilibrium?

	Entropy	Gibbs free energy
A.	maximum	maximum
B.	maximum	minimum
C.	minimum	maximum
D.	minimum	minimum

25. What is the difference between a conjugate Brønsted–Lowry acid–base pair?
- A. Electron pair
 - B. Positive charge
 - C. Proton
 - D. Hydrogen atom

26. Which is an example of an amphiprotic species?
- A. Al_2O_3
 - B. CO_3^{2-}
 - C. P_4O_{10}
 - D. HPO_4^{2-}

27. Which can act as a Lewis acid but not a Brønsted–Lowry acid?
- A. BF_3
 - B. H_2O
 - C. NF_3
 - D. NH_3

28. What is the order, in increasing pH, of the following solutions of equal concentration?

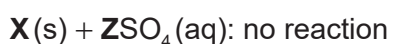
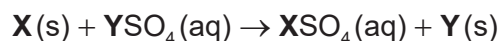
	pKa		Ka
$\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$	4.8	CHCl_2COOH	5.0×10^{-2}
$\text{CH}_3\text{CH}_2\text{COOH}$	4.9	H_3BO_3	5.8×10^{-10}

- A. $\text{H}_3\text{BO}_3 < \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH} < \text{CHCl}_2\text{COOH}$
- B. $\text{H}_3\text{BO}_3 < \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} < \text{CHCl}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH}$
- C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH} < \text{CHCl}_2\text{COOH} < \text{H}_3\text{BO}_3$
- D. $\text{CHCl}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH} < \text{H}_3\text{BO}_3$

29. In which species does sulfur have the same oxidation state as in SO_3^{2-} ?

- A. $\text{S}_2\text{O}_3^{2-}$
- B. SO_4^{2-}
- C. H_2S
- D. SOCl_2

30. The following occurs when metal **X** is added to **Y** sulfate solution and **Z** sulfate solution. (**X**, **Y** and **Z** represent metal elements but not their symbols.)



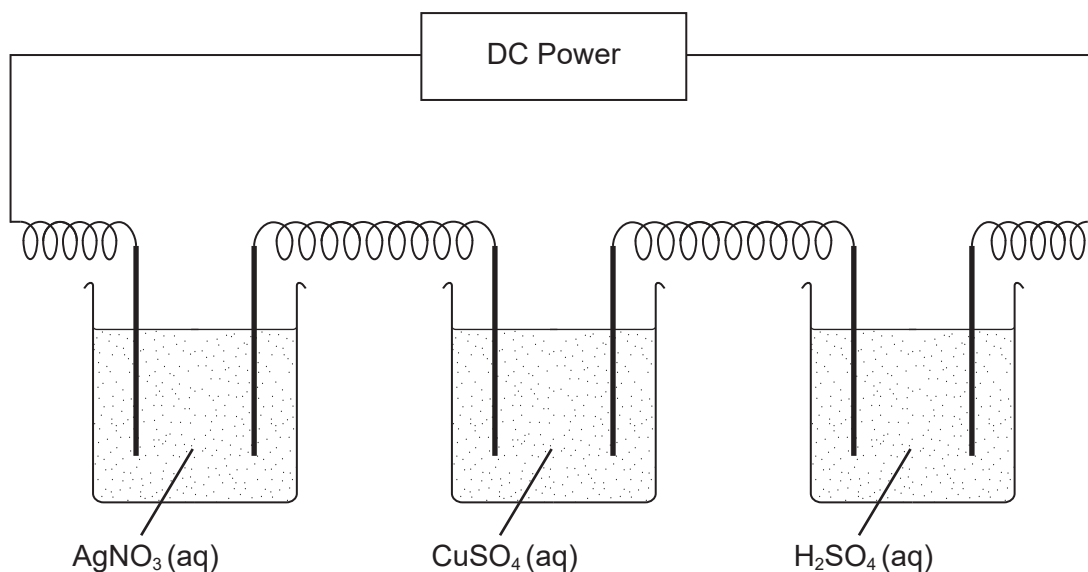
What is the order of increasing reactivity?

- A. $\text{X} < \text{Y} < \text{Z}$
- B. $\text{Y} < \text{X} < \text{Z}$
- C. $\text{Z} < \text{Y} < \text{X}$
- D. $\text{Z} < \text{X} < \text{Y}$

31. What are the products of electrolysis of concentrated aqueous sodium bromide?

	Positive electrode	Negative electrode
A.	Br_2	Na
B.	O_2	H_2
C.	O_2	Na
D.	Br_2	H_2

32. Three cells with platinum electrodes are connected in series to a DC power supply.



What is the ratio of moles formed at each cathode (negative electrode)?

	Ag(s)	Cu(s)	H ₂ (g)
A.	1	2	1
B.	2	1	1
C.	2	1	2
D.	1	2	2

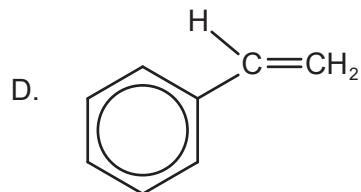
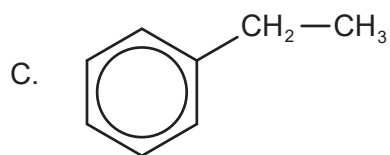
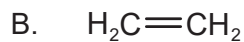
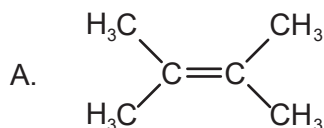
33. Which compound is **not** in the same homologous series as the others?

- A. C_5H_{12}
- B. C_6H_{12}
- C. C_7H_{16}
- D. C_8H_{18}

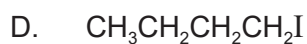
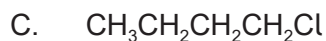
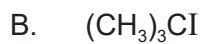
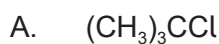
34. Which will react with a halogen by an electrophilic substitution mechanism?

- A.
- B.
- C.
- D.

35. Which compound **cannot** undergo addition polymerization?



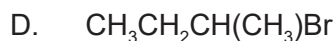
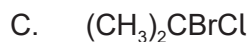
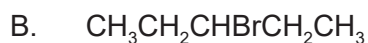
36. In which compound is the halogen substituted the most rapidly by aqueous hydroxide ions?



37. Which can be reduced to an aldehyde?



38. Which can show optical activity?



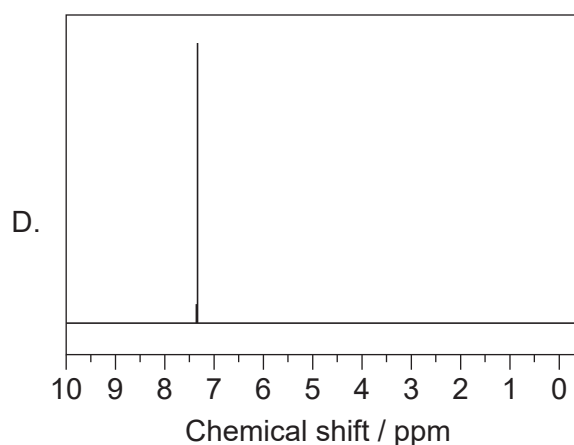
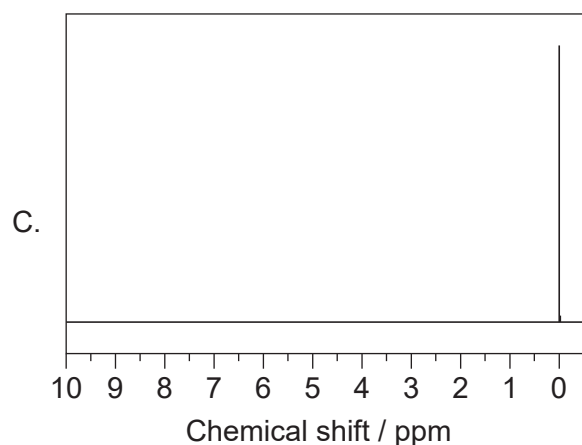
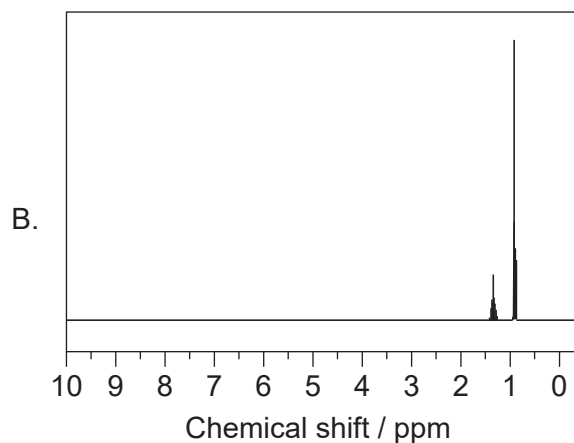
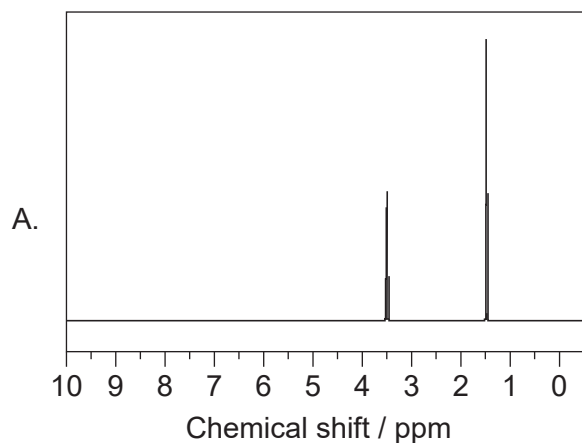
39. What is the value of the temperature change?

Initial temperature: $2.0 \pm 0.1^\circ\text{C}$

Final temperature: $15.0 \pm 1.0^\circ\text{C}$

- A. $13.0 \pm 0.1^\circ\text{C}$
- B. $13.0 \pm 0.9^\circ\text{C}$
- C. $13.0 \pm 1.0^\circ\text{C}$
- D. $13.0 \pm 1.1^\circ\text{C}$

40. Which is the ^1H NMR spectrum of tetramethylsilane, TMS, $(\text{CH}_3)_4\text{Si}$?



[Source: ISDBS, National Institute of Advanced Industrial Science and Technology. Used with permission.]