Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

Wednesday 8 November 2017 (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]**.

8817 – 6101

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			Atomic number **Element** Relative atomic mass														2 **He** 4.00
2	3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	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
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)

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	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** (262)

1. How many atoms of nitrogen are there in 0.50 mol of $(NH_4)_2CO_3$?

A. 1

B. 2

C. 3.01×10^{23}

D. 6.02×10^{23}

2. Which solution neutralizes 50.0 cm^3 of 0.120 mol dm^{-3} NaOH (aq)?

A. 12.5 cm^3 of 0.080 mol dm^{-3} H_3PO_4

B. 25.0 cm^3 of 0.120 mol dm^{-3} CH_3COOH

C. 25.0 cm^3 of 0.120 mol dm^{-3} H_2SO_4

D. 50.0 cm^3 of 0.060 mol dm^{-3} HNO_3

3. What is the pressure, in Pa, inside a 1.0 m^3 cylinder containing 10 kg of H_2 (g) at 25 ºC?
$R = 8.31\ J\ K^{-1}\ mol^{-1}$; $pV = nRT$

A. $\frac{1 \times 10^4 \times 8.31 \times 25}{1.0 \times 10^3}$

B. $\frac{5 \times 10^2 \times 8.31 \times 298}{1.0}$

C. $\frac{1 \times 8.31 \times 25}{1.0 \times 10^3}$

D. $\frac{5 \times 10^3 \times 8.31 \times 298}{1.0}$

4. A compound with $M_r = 102$ contains 58.8 % carbon, 9.80 % hydrogen and 31 % oxygen by mass. What is its molecular formula?
A_r: C = 12.0; H = 1.0; O = 16.0

A. $C_2H_{14}O_4$

B. $C_3H_4O_4$

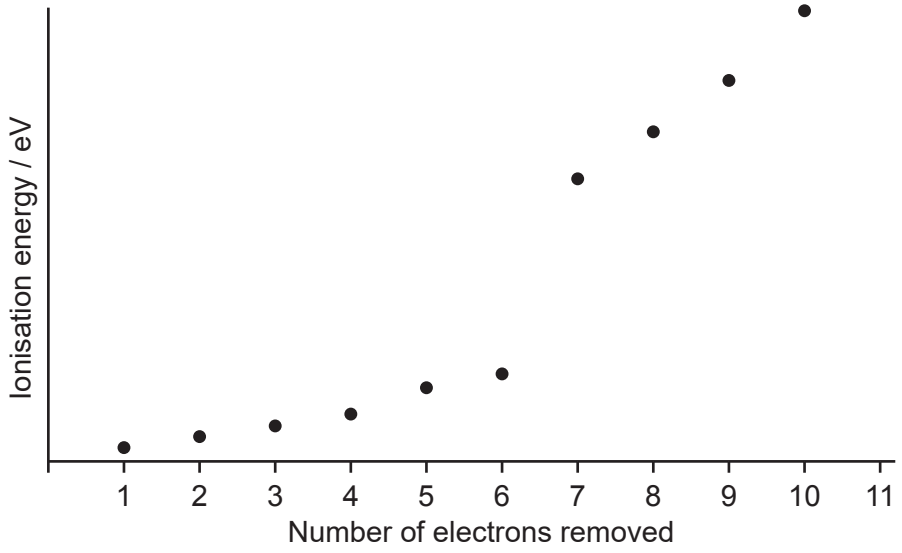
C. $C_5H_{10}O_2$

D. $C_6H_{14}O$

5. What is the number of protons and the number of neutrons in ^{131}I?

	Protons	Neutrons
A.	53	78
B.	53	131
C.	78	53
D.	131	53

6. The graph represents the first ten ionisation energies (IE) of an element.



What is the element?

A. O

B. S

C. Ne

D. Cl

7. Which electron configuration is that of a transition metal atom in the ground state?

A. $[Ne]3s^2 3p^6 4s^1$

B. $[Ar]3d^9$

C. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$

D. $[Ar]4s^1 3d^5$

8. Which trends are correct across period 3 (from Na to Cl)?

I. Atomic radius decreases
II. Melting point increases
III. First ionization energy increases

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

9. Which oxide dissolves in water to give a solution with a pH below 7?

A. MgO

B. Li_2O

C. CaO

D. P_4O_{10}

10. $[CoCl_6]^{3-}$ is orange while $[Co(NH_3)_6]^{3+}$ is yellow. Which statement is correct?

A. $[CoCl_6]^{3-}$ absorbs orange light.

B. The oxidation state of cobalt is different in each complex.

C. The different colours are due to the different charges on the complex.

D. The different ligands cause different splitting in the 3d orbitals.

11. Which of the following series shows increasing hydrogen bonding with water?

A. Propane < propanal < propanol < propanoic acid

B. Propane < propanol < propanal < propanoic acid

C. Propanal < propane < propanoic acid < propanol

D. Propanoic acid < propanol < propanal < propane

12. The electronegativity values of four elements are given.

C	N	O	F
2.6	3.0	3.4	4.0

What is the order of **increasing** polarity of the **bonds** in the following compounds?

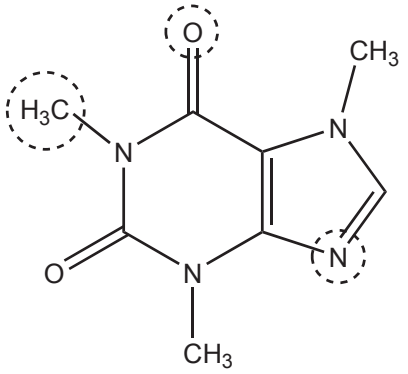
A. $CO < OF_2 < NO < CF_4$

B. $CF_4 < CO < OF_2 < NO$

C. $NO < OF_2 < CO < CF_4$

D. $CF_4 < NO < OF_2 < CO$

13. What is the hybridization state and electron domain geometry around the circled C, N and O atoms?



	C	O	N
A.	sp^3 and tetrahedral	sp^2 and trigonal planar	sp^2 and trigonal planar
B.	sp^2 and trigonal planar	sp and linear	sp^3 and tetrahedral
C.	sp^3 and tetrahedral	sp and linear	sp^2 and trigonal planar
D.	sp^3 and trigonal pyramidal	sp^2 and trigonal planar	sp^3 and trigonal pyramidal

14. How many sigma (σ) and pi (π) bonds are present in this molecule?

	σ	π
A.	12	6
B.	14	5
C.	16	6
D.	17	5

15. Which statements are correct for ionic compounds?

I. Lattice energy increases as ionic radii increase.
II. Within the same group, the melting point of salts tends to decrease as the radius of the cation increases.
III. Solubility in water depends on the relative magnitude of the lattice energy compared to the hydration energy.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

16. What is the standard enthalpy of formation, in $kJ\,mol^{-1}$, of IF (g)?

$$IF_7(g) + I_2(s) \rightarrow IF_5(g) + 2IF(g) \qquad \Delta H^{\ominus} = -89\,kJ$$

$\Delta H_f^{\ominus}(IF_7) = -941\,kJ\,mol^{-1}$
$\Delta H_f^{\ominus}(IF_5) = -840\,kJ\,mol^{-1}$

A. –190

B. –95

C. +6

D. +95

17. The combustion of glucose is exothermic and occurs according to the following equation:

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$$

Which is correct for this reaction?

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$	**Spontaneous/ non-spontaneous**
A.	negative	positive	spontaneous
B.	negative	positive	non-spontaneous
C.	positive	negative	spontaneous
D.	positive	positive	non-spontaneous

18. Which equation represents the lattice enthalpy of magnesium sulfide?

A. $MgS(s) \rightarrow Mg(g) + S(g)$

B. $MgS(s) \rightarrow Mg^{+}(g) + S^{-}(g)$

C. $MgS(s) \rightarrow Mg^{2+}(g) + S^{2-}(g)$

D. $MgS(s) \rightarrow Mg(s) + S(s)$

19. The enthalpy change for the dissolution of NH_4NO_3 is $+26\,kJ\,mol^{-1}$ at 25 °C. Which statement about this reaction is correct?

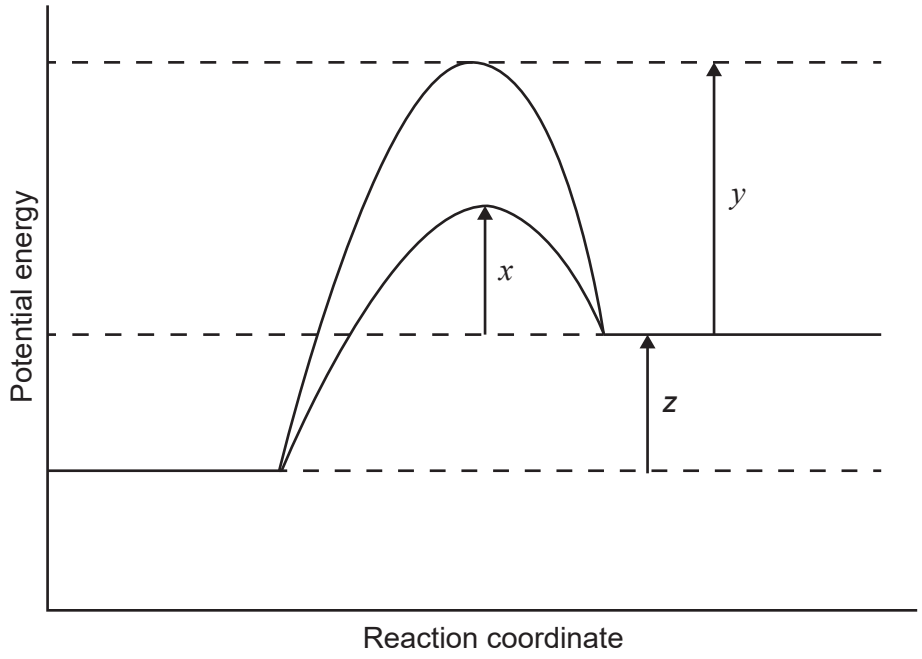
A. The reaction is exothermic and the solubility decreases at higher temperature.

B. The reaction is exothermic and the solubility increases at higher temperature.

C. The reaction is endothermic and the solubility decreases at higher temperature.

D. The reaction is endothermic and the solubility increases at higher temperature.

20. The diagram shows the energy profile for a catalysed and uncatalysed reaction.
Which represents the enthalpy change, ΔH, and the activation energy, E_a, for the **catalysed** reaction?



	ΔH	E_a (catalysed reaction)
A.	z	$x + z$
B.	z	$z + y$
C.	$-z$	x
D.	$z + x$	x

21. The rate expression for the reaction $X(g) + 2Y(g) \rightarrow 3Z(g)$ is

$$\text{rate} = k[X]^0 [Y]^2$$

By which factor will the rate of reaction increase when the concentrations of X and Y are both increased by a factor of 3?

A. 6

B. 9

C. 18

D. 27

22. Which pair of statements explains the increase in rate of reaction when the temperature is increased or a catalyst is added?

	Increasing temperature	**Adding a catalyst**
A.	average kinetic energy of particles increases	activation energy increases
B.	enthalpy change of reaction decreases	average kinetic energy of particles increases
C.	average kinetic energy of particles increases	activation energy decreases
D.	activation energy increases	enthalpy change of reaction decreases

23. At 700 ºC, the equilibrium constant, K_c, for the reaction is 1.075×10^8.

$$2H_2(g) + S_2(g) \rightleftharpoons 2H_2S(g)$$

Which relationship is always correct for the equilibrium at this temperature?

A. $[H_2S]^2 < [H_2]^2 [S_2]$

B. $[S_2] = 2[H_2S]$

C. $[H_2S] < [S_2]$

D. $[H_2S]^2 > [H_2]^2[S_2]$

24. What will happen if the pressure is increased in the following reaction mixture at equilibrium?

$$CO_2(g) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

A. The equilibrium will shift to the right and pH will decrease.

B. The equilibrium will shift to the right and pH will increase.

C. The equilibrium will shift to the left and pH will increase.

D. The equilibrium will shift to the left and pH will decrease.

25. $10.0\,cm^3$ of an aqueous solution of sodium hydroxide of pH = 10 is mixed with $990.0\,cm^3$ of distilled water. What is the pH of the resulting solution?

A. 8

B. 9

C. 11

D. 12

26. Which of the following will form a buffer solution if combined in appropriate molar ratios?

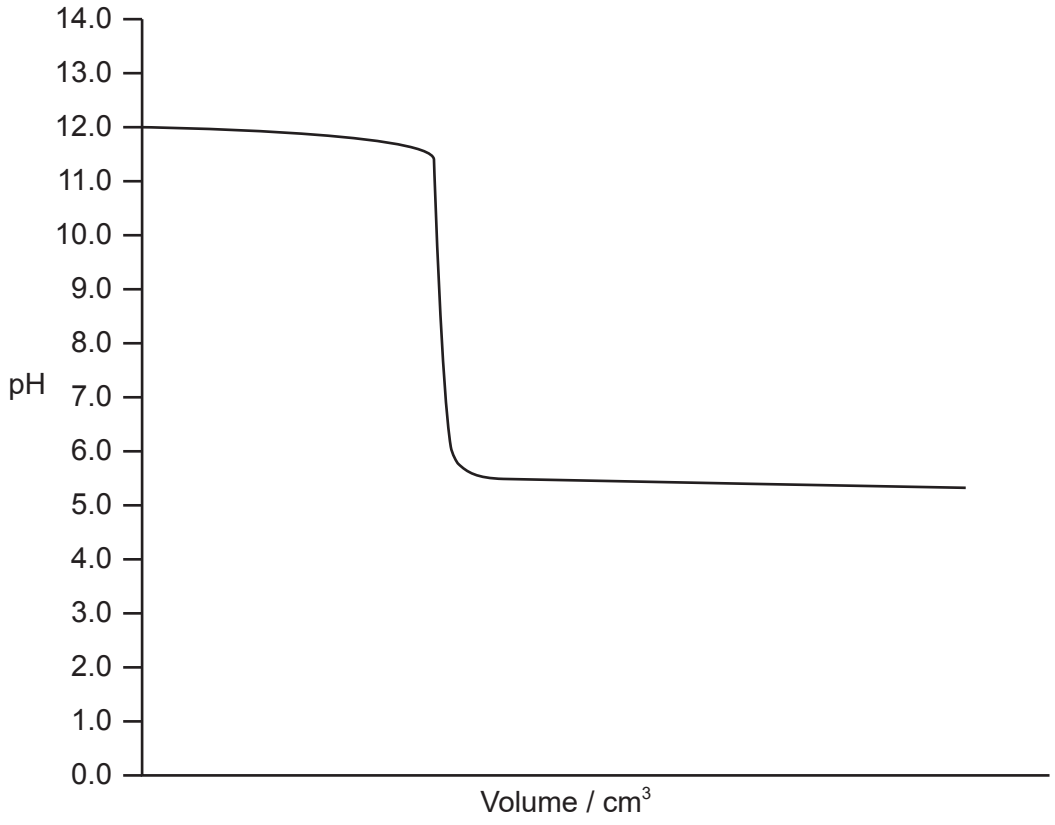
A. HCl and NaCl

B. NaOH and HCOONa

C. NH_4Cl and HCl

D. HCl and NH_3

27. Which indicator is appropriate for the acid-base titration shown below?



A. Thymol blue ($pK_a = 1.5$)

B. Methyl orange ($pK_a = 3.7$)

C. Bromophenol blue ($pK_a = 4.2$)

D. Phenolphthalein ($pK_a = 9.6$)

28. Which statement is **incorrect** for a $0.10\,mol\,dm^{-3}$ HCOOH solution?

A. pH = 1

B. $[H^+] << 0.10\,mol\,dm^{-3}$

C. $[HCOO^-]$ is approximately equal to $[H^+]$

D. HCOOH is partially ionized

29. Which of the following is a redox reaction?

A. $3Mg(s) + 2AlCl_3(aq) \rightarrow 2Al(s) + 3MgCl_2(aq)$

B. $SiO_2(s) + 2NaOH(aq) \rightarrow Na_2SiO_3(aq) + H_2O(l)$

C. $KCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + KNO_3(aq)$

D. $2NaHCO_3(aq) \rightarrow Na_2CO_3(aq) + CO_2(g) + H_2O(l)$

30. Consider the following half-equations:

$$\underset{\text{(brown)}}{I_2(s)} + 2e^- \rightleftharpoons \underset{\text{(colourless)}}{2I^-(aq)} \qquad E^\ominus = +0.54\,V$$

$$\underset{\text{(purple)}}{MnO_4^-(aq)} + 8H^+(aq) + 5e^- \rightleftharpoons \underset{\text{(colourless)}}{Mn^{2+}(aq)} + 4H_2O(l) \qquad E^\ominus = +1.51\,V$$

Which statement is correct for the reaction between $KMnO_4(aq)$ and $KI(aq)$ in acidic conditions?

A. MnO_4^- reduces I^- to I_2.

B. I^- reduces MnO_4^- to Mn^{2+}.

C. The colour changes from brown to purple.

D. MnO_4^- is oxidized to Mn^{2+}.

31. What are the products when an aqueous solution of copper(II) sulfate is electrolysed using inert graphite electrodes?

	Cathode (negative electrode)	**Anode (positive electrode)**
A.	$Cu(s)$	$H_2(g)$
B.	$O_2(g)$	$Cu(s)$
C.	$Cu(s)$	$O_2(g)$
D.	$H_2(g)$	$O_2(g)$

32. What are the oxidation states of chromium in $(NH_4)_2Cr_2O_7(s)$ and $Cr_2O_3(s)$?

	$(NH_4)_2Cr_2O_7(s)$	**$Cr_2O_3(s)$**
A.	+7	+3
B.	+6	+3
C.	+6	+6
D.	+7	+6

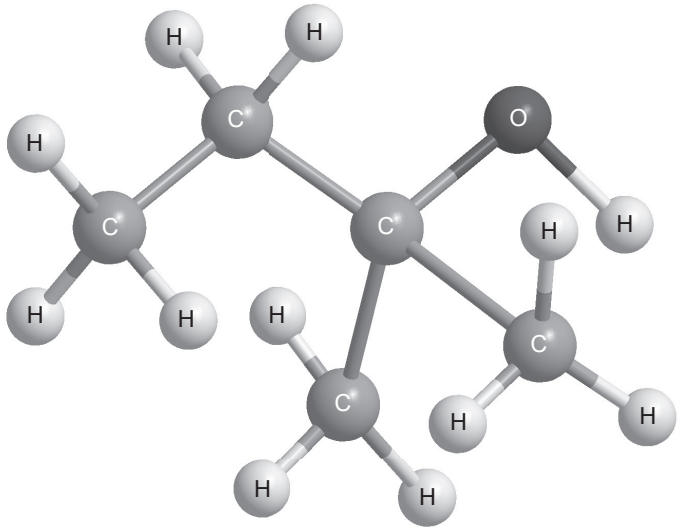
33. Propene reacts separately with H_2O/H^+ and H_2/Ni to give products **X** and **Z** respectively.

$$\mathbf{X} \xleftarrow{H_2O/H^+} CH_3{-}CH{=}CH_2 \xrightarrow{H_2/Ni} \mathbf{Z}$$

What are the major products of the reactions?

	X	**Z**
A.	$CH_3CH(OH)CH_3$	$CH_3CH_2CH_3$
B.	$CH_3CH_2CH_2OH$	$CH_3C{\equiv}CH$
C.	$CH_3C(O)CH_3$	$CH_3CH_2CH_3$
D.	$CH_3CH(OH)CH_3$	$CH_3C{\equiv}CH$

34. What is the name of this compound, using IUPAC rules?



A. 3-methylbutan-3-ol

B. 2-ethylpropan-2-ol

C. 2-methylbutan-2-ol

D. 3-methylbutan-2-ol

35. What is the product of the reaction between pentan-2-one and sodium borohydride, $NaBH_4$?

A. Pentan-1-ol

B. Pentan-2-ol

C. Pentanoic acid

D. Pentanal

36. Which compound can be oxidized when heated with an acidified solution of potassium dichromate(VI)?

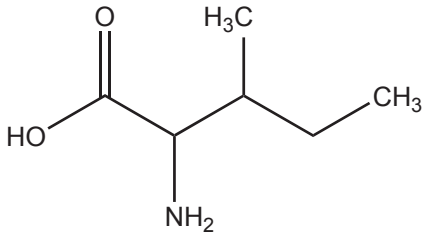
A. $CH_3C(O)CH_2CH_3$

B. $CH_3CH_2CH(OH)CH_3$

C. $(CH_3)_3COH$

D. $CH_3(CH_2)_2COOH$

37. What is the number of optical isomers of isoleucine?



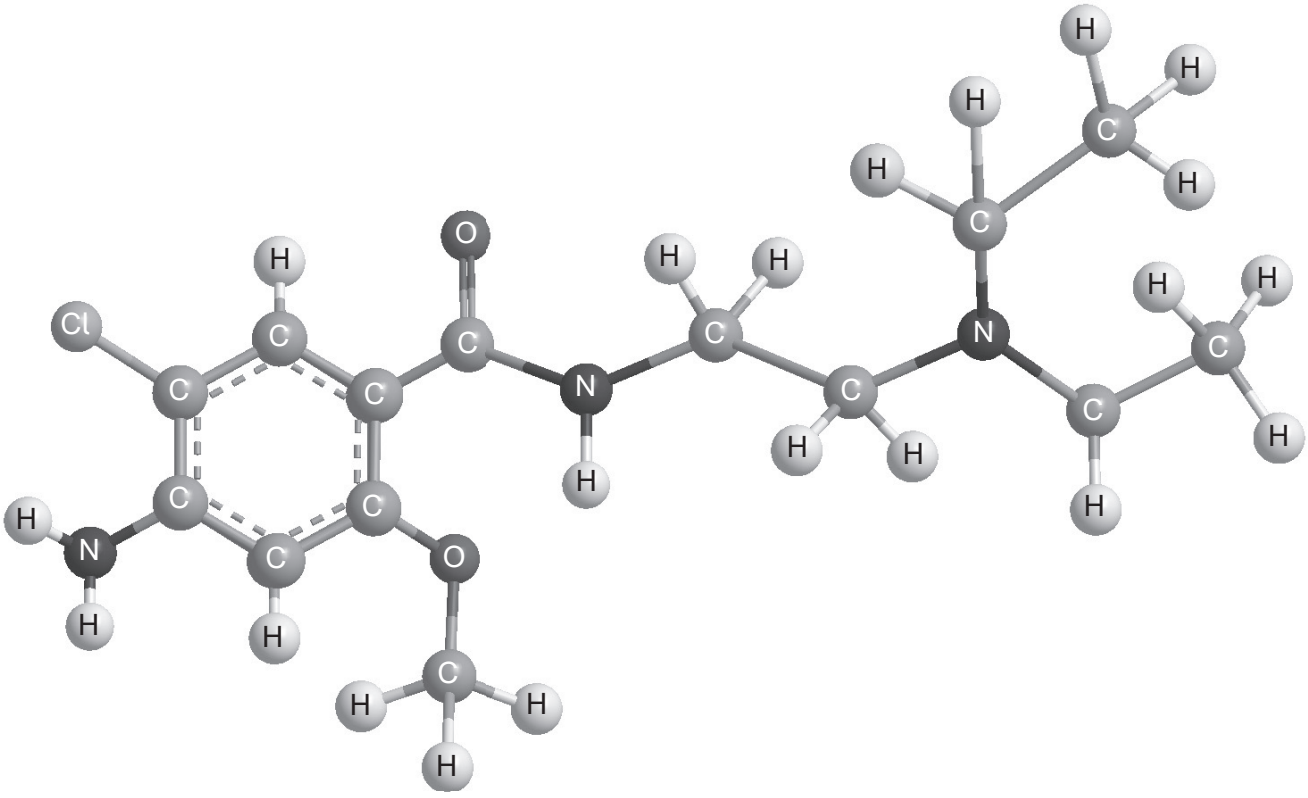
A. 0

B. 2

C. 4

D. 8

38. Which functional group is responsible for the pK_b of 4.1 in this compound?



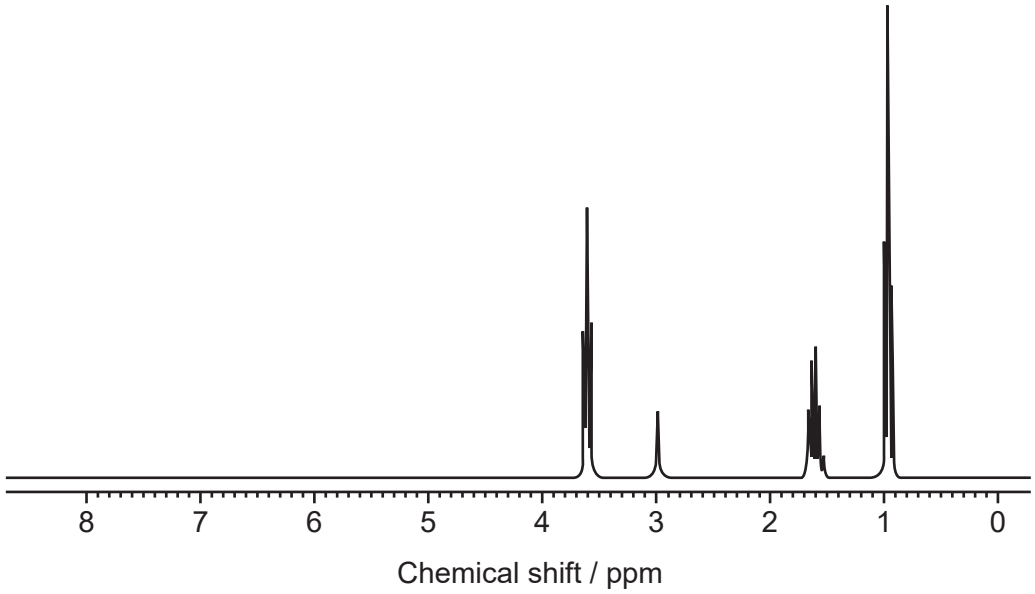
A. Amido

B. Amino

C. Chloro

D. Ether

39. Which compound gives this ^{1}H NMR spectrum?



A. $CH_3CH_2OCH_2CH_3$

B. CH_3CH_2OH

C. $CH_3CH_2CH_3$

D. $CH_3CH_2CH_2OH$

40. A student performs an acid-base titration using a pH meter, but forgets to calibrate it. Which type of error will occur and how will it affect the quality of the measurements?

A. Random error and lower precision

B. Systematic error and lower accuracy

C. Systematic error and lower precision

D. Random error and lower accuracy