

**Chemistry**  
**Higher level**  
**Paper 1**

Friday 13 November 2015 (afternoon)

1 hour

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**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]**.

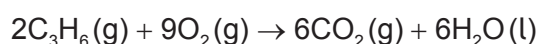
## The Periodic Table

1	2	3	4	5	6	7	0										
1 <b>H</b> 1.01		Atomic number						2 <b>He</b> 4.00									
3 <b>Li</b> 6.94	4 <b>Be</b> 9.01	<b>Element</b>					9 <b>F</b> 19.00	10 <b>Ne</b> 20.18									
11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31	Relative Atomic Mass					17 <b>Cl</b> 35.45	18 <b>Ar</b> 39.95									
19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.90	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.71	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.37	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.59	33 <b>As</b> 74.92	34 <b>Se</b> 78.96	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.80
37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.94	43 <b>Tc</b> 98.91	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.40	49 <b>In</b> 114.82	50 <b>Sn</b> 118.69	51 <b>Sb</b> 121.75	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.30
55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.34	57 † <b>La</b> 138.91	72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.85	75 <b>Re</b> 186.21	76 <b>Os</b> 190.21	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.09	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.37	82 <b>Pb</b> 207.19	83 <b>Bi</b> 208.98	84 <b>Po</b> (210)	85 <b>At</b> (210)	86 <b>Rn</b> (222)
87 <b>Fr</b> (223)	88 <b>Ra</b> (226)	89 ‡ <b>Ac</b> (227)															
								†									
			58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> 146.92	62 <b>Sm</b> 150.35	63 <b>Eu</b> 151.96	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.92	66 <b>Dy</b> 162.50	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.93	70 <b>Yb</b> 173.04	71 <b>Lu</b> 174.97	
								‡									
			90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> (237)	94 <b>Pu</b> (242)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (254)	100 <b>Fm</b> (257)	101 <b>Md</b> (258)	102 <b>No</b> (259)	103 <b>Lr</b> (260)	

1. Which compound's molecular formula is the same as its empirical formula?

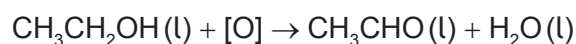
- A.  $C_2H_5OH$
- B.  $CH_3COOH$
- C.  $C_6H_6$
- D.  $C_8H_{18}$

2. The equation for the **complete** combustion of propene,  $C_3H_6$ , is shown below.



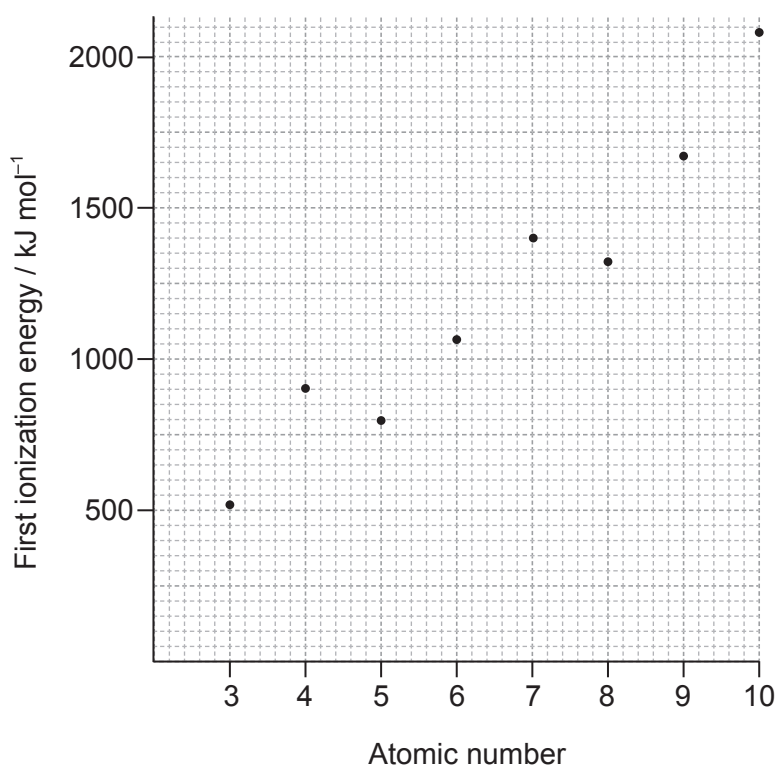
Which mixture, when ignited, will lead to **incomplete** combustion and the formation of  $CO(g)$ ?

- A.  $2\text{ dm}^3$  of propene and  $10\text{ dm}^3$  of oxygen
  - B.  $0.5\text{ dm}^3$  of propene and  $2.3\text{ dm}^3$  of oxygen
  - C.  $1\text{ dm}^3$  of propene and  $4\text{ dm}^3$  of oxygen
  - D.  $3\text{ dm}^3$  of propene and  $14\text{ dm}^3$  of oxygen
3. What is the percentage yield when  $1.1\text{ g}$  of ethanal,  $CH_3CHO$ , is obtained from  $4.6\text{ g}$  of ethanol,  $CH_3CH_2OH$ ?  $M_r(CH_3CH_2OH) = 46$ ;  $M_r(CH_3CHO) = 44$



- A.  $\frac{1.1 \times 46 \times 100}{44 \times 4.6}$
- B.  $\frac{1.1 \times 100}{4.6}$
- C.  $\frac{4.6 \times 44 \times 100}{4.6 \times 1.1}$
- D.  $\frac{1.1 \times 46}{44 \times 4.6}$

4. Which stage of operation immediately follows ionization in the mass spectrometer?
- Acceleration
  - Deflection
  - Detection
  - Vaporization
5. Which statement is correct about the first ionization energies of consecutive elements shown in the graph?



[Source: Values from Nuffield Advance Science - Book of Data, Revised Edition (1984)]

- The graph falls between Be and B because there is an electron in the third energy level.
- The graph increases from B to N because the atomic radius is increasing.
- The graph increases from Li to Ne because the number of electrons is increasing.
- The graph falls between Be and B because the outer electron in B is in a p sub-level.

6. Which element has the greatest first ionization energy?
- A. Al
  - B. Ar
  - C. Cl
  - D. Cs
7. Which elements are in the same group of the periodic table?
- A. Ca, Na, Rb, Sr
  - B. Al, Ar, Cl, S
  - C. Au, Hg, Pb, Pt
  - D. As, Bi, P, Sb
8. Which property of transition metals enables them to behave as catalysts?
- A. High melting point
  - B. Variable oxidation number
  - C. High density
  - D. Split d sub-levels
9. Which statement best describes the lattice structure of solid sodium chloride?
- A. Each sodium ion is surrounded by one chloride ion.
  - B. Each chloride ion is surrounded by two sodium ions.
  - C. Each chloride ion is surrounded by four sodium ions.
  - D. Each sodium ion is surrounded by six chloride ions.
10. Which compound is most likely to contain ionic bonding?
- A.  $\text{ClO}_2$
  - B.  $\text{CsCl}$
  - C.  $\text{SCl}_2$
  - D.  $\text{SiCl}_4$

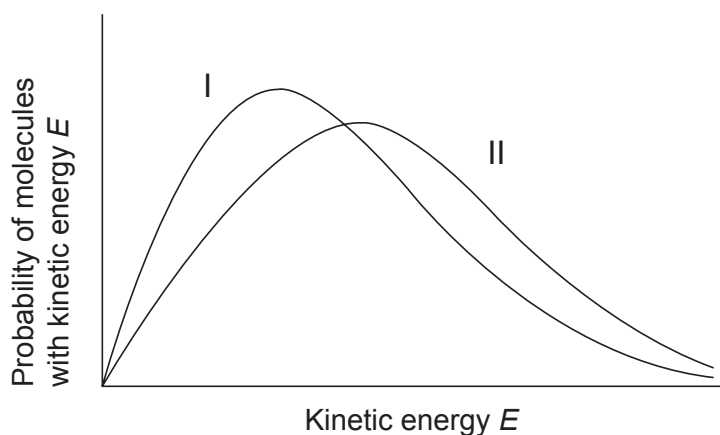
11. Which molecule is polar?
- A.  $C_2H_6$
  - B.  $CH_2Cl_2$
  - C.  $CO_2$
  - D.  $CCl_4$
12. What is the shape of the hexacyanoferrate(III) ion,  $[Fe(CN)_6]^{3-}$ ?
- A. Square planar
  - B. Hexagonal
  - C. Octahedral
  - D. Trigonal bipyramidal
13. Which set contains two or more species with delocalized  $\pi$  electrons?
- A.  $CH_3CH_3$ ,  $H_2C=CH_2$ ,  $H_2C=O$
  - B.  $NaCl$ ,  $C_6H_6$ ,  $H_2C=O$
  - C.  $CO_3^{2-}$ ,  $C_6H_6$ ,  $C_6H_{12}$
  - D.  $O_2$ ,  $CH_3COCH_3$ ,  $CH_3COOCH_3$
14. Which of the following changes are exothermic?
- I.  $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$
  - II.  $2C_8H_{18}(g) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$
  - III.  $C_8H_{18}(g) \rightarrow C_8H_{18}(l)$
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

15. Which change represents the standard enthalpy change of formation?
- The formation of 1 mol of a compound in its standard state from its gaseous atoms
  - The formation of 1 mol of a compound in its standard state from its elements
  - The formation of 1 mol of a compound in its standard state from its gaseous atoms in their standard states
  - The formation of 1 mol of a compound in its standard state from its elements in their standard states
16. Which equation represents electron affinity?
- $C(g) + e^- \rightarrow C^-(g)$
  - $Na^+(aq) + e^- \rightarrow Na(s)$
  - $\frac{1}{2}Cl_2(g) + e^- \rightarrow Cl^-(g)$
  - $B(g) + e^- \rightarrow B^+(g) + 2e^-$
17. Which combination results in an ionic compound having the **greatest** magnitude of lattice enthalpy?

	Sum of ionic radii	Ionic charges
A.	small	large
B.	large	large
C.	large	small
D.	small	small

18. Under which conditions does a sample of the same mass of carbon dioxide have the **lowest** entropy value?
- Solid at high temperature
  - Solid at low temperature
  - Gas at high temperature
  - Gas at low temperature

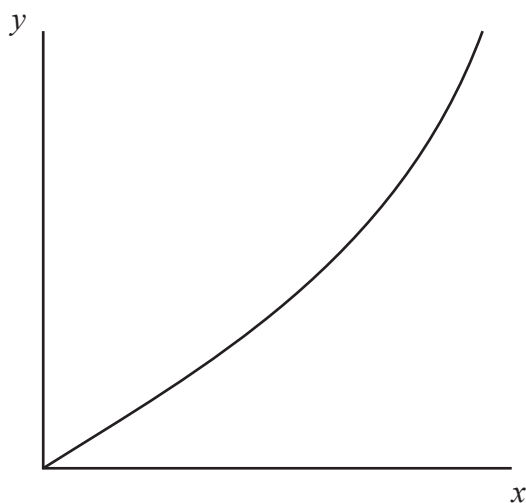
19. Curves I and II represent samples of the same gas at a constant pressure but at different temperatures. The areas under curves I and II are equal. What does curve II represent?



- A. Curve II is at the lower temperature and there are less molecules in the sample.
- B. Curve II is at the lower temperature and there are the same number of molecules in the samples.
- C. Curve II is at the higher temperature and there are more molecules in the sample.
- D. Curve II is at the higher temperature and there are the same number of molecules in the samples.



20. The graph shows a plot for a reaction with second-order kinetics. How should the axes be labelled?



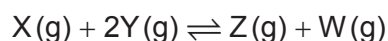
	<b>x-axis</b>	<b>y-axis</b>
A.	concentration	time
B.	time	concentration
C.	rate	concentration
D.	concentration	rate

21. Which factors affect the rate constant,  $k$ , of a reaction?

- I. Catalyst
  - II. Concentration of reactants
  - III. Temperature
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

22. Which best describes a reaction in a state of equilibrium?
- A. The rates of the forward and reverse reactions are zero and the concentrations of products and reactants are equal.
  - B. The rate of the forward reaction equals the rate of the reverse reaction and the concentrations of products and reactants are equal.
  - C. The rates of the forward and reverse reactions are zero and the concentrations of products and reactants are constant.
  - D. The rate of the forward reaction equals the rate of the reverse reaction and the concentrations of products and reactants are constant.

23. The equilibrium concentrations of X, Y, Z and W are 1, 2, 4 and 2 mol dm<sup>-3</sup> respectively.



What is the value of the equilibrium constant,  $K_c$ ?

- A. 0.25
  - B. 0.5
  - C. 2
  - D. 4
24. Which of the following molecules can act as a Lewis acid but not as a Brønsted–Lowry acid?
- A.  $\text{BF}_3$
  - B.  $\text{PCl}_3$
  - C.  $\text{NH}_3$
  - D.  $\text{H}_2\text{O}$
25. Which is a 0.001 mol dm<sup>-3</sup> solution of a weak acid?

	Conductivity	pH
A.	poor	5
B.	good	7
C.	poor	10
D.	good	3

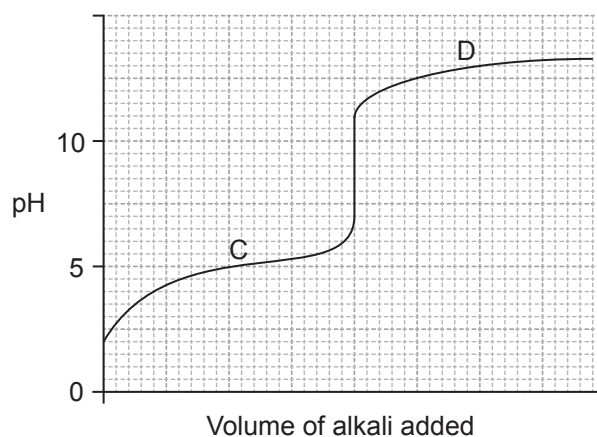
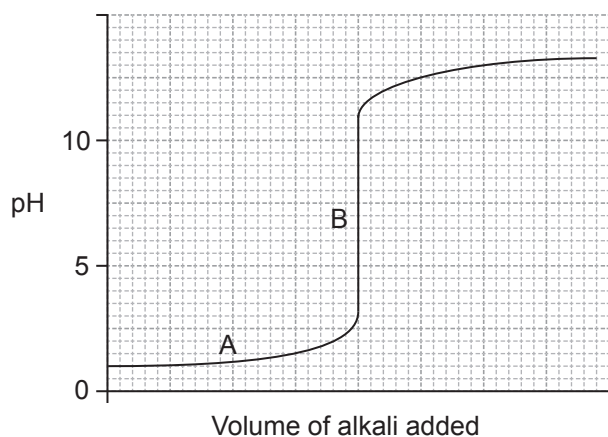
26. What is the order of increasing acid strength? Approximate  $K_a$  and  $pK_a$  values at 298 K are given.

	$K_a$		$pK_a$
$\text{ClCH}_2\text{COOH}$	$1 \times 10^{-3}$	$\text{C}_6\text{H}_5\text{OH}$	10.0
$\text{CH}_3\text{CH}_2\text{COOH}$	$1 \times 10^{-5}$	$\text{C}_6\text{H}_5\text{NH}_3^+$	4.6

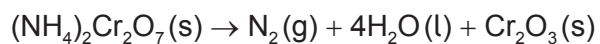
- A.  $\text{ClCH}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH} < \text{C}_6\text{H}_5\text{NH}_3^+ < \text{C}_6\text{H}_5\text{OH}$
- B.  $\text{C}_6\text{H}_5\text{OH} < \text{C}_6\text{H}_5\text{NH}_3^+ < \text{ClCH}_2\text{COOH} < \text{CH}_3\text{CH}_2\text{COOH}$
- C.  $\text{C}_6\text{H}_5\text{OH} < \text{C}_6\text{H}_5\text{NH}_3^+ < \text{CH}_3\text{CH}_2\text{COOH} < \text{ClCH}_2\text{COOH}$
- D.  $\text{C}_6\text{H}_5\text{OH} < \text{CH}_3\text{CH}_2\text{COOH} < \text{C}_6\text{H}_5\text{NH}_3^+ < \text{ClCH}_2\text{COOH}$
27. Which solutions, mixed in equal concentrations and volumes, form an acid buffer solution?
- A.  $\text{HCl}(\text{aq}) + \text{NaCl}(\text{aq})$
- B.  $\text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{CH}_3\text{CO}_2\text{Na}(\text{aq})$
- C.  $\text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{NaOH}(\text{aq})$
- D.  $\text{CH}_3\text{CO}_2\text{H}(\text{aq}) + \text{CH}_3\text{CH}_2\text{CO}_2\text{H}(\text{aq})$
28. Which salt forms the most acidic solution when dissolved in water?

	Salt	Ionic radius of cation / $10^{-12} \text{ m}$
A.	$\text{CrCl}_3$	63
B.	$\text{FeCl}_2$	76
C.	$\text{MgCl}_2$	65
D.	$\text{NaCl}$	98

29. What is the buffer region in the acid–base titration curves below?



30. Which element undergoes reduction in the following reaction?

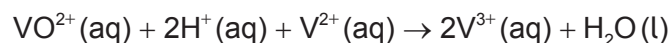


- A. Cr
- B. H
- C. N
- D. O

31. Which best describes reduction?

- A. Increase in oxidation number and gain of electrons
- B. Increase in oxidation number and loss of electrons
- C. Decrease in oxidation number and gain of electrons
- D. Decrease in oxidation number and loss of electrons

32. What is  $E^\ominus$ , in V, for the following reaction?

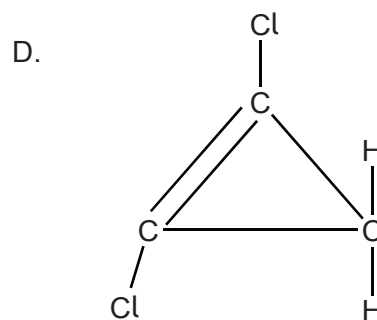
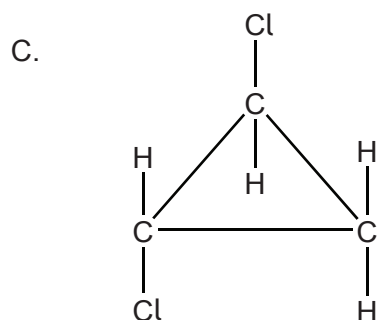
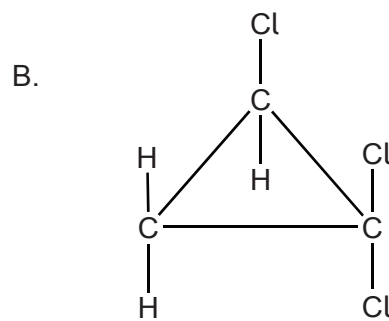
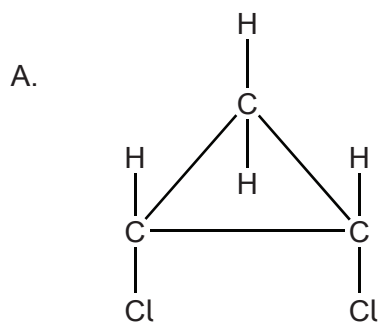


	Standard electrode potential, $E^\ominus / \text{V}$
$\text{V}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{V}(\text{s})$	–1.18
$\text{V}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{V}^{2+}(\text{aq})$	–0.26
$\text{VO}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.34
$\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+1.00

- A. –0.60
- B. +0.08
- C. +0.60
- D. +1.26
33. What product is formed at the positive electrode (anode) when  $0.001 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4(\text{aq})$  is electrolysed?
- A. Hydrogen
- B. Oxygen
- C. Sulfur
- D. Sulfur dioxide
34. Which pair of compounds can be distinguished by reacting them with dilute bromine water in the dark?
- A.  $\text{CH}_3\text{CH}_2\text{COOH}$  and  $\text{CH}_3\text{CH}_2\text{CHO}$
- B.  $\text{CH}_3\text{CH}_2\text{CHCHCH}_3$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
- C.  $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)_2$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$
- D.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHBrCH}_3$  and  $\text{CH}_3\text{CH}_2\text{CHBrCH}_2\text{CH}_3$

35. Which compound is most soluble in water?
- A.  $\text{CH}_3\text{CH}_2\text{CHO}$
  - B.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$
  - C.  $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$
  - D.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$
36. Which are features of successive members of a homologous series?
- I. Similar chemical properties
  - II. Same general formula
  - III. Differ by  $-\text{CH}_2-$
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III
37. Which formula represents propanenitrile?
- A.  $\text{CH}_3\text{CH}_2\text{CN}$
  - B.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CN}$
  - C.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$
  - D.  $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_3$
38. Which halogenoalkane reacts fastest with warm  $\text{NaOH}(\text{aq})$ ?
- A.  $(\text{CH}_3)_3\text{CCl}$
  - B.  $(\text{CH}_3)_3\text{CBr}$
  - C.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl}$
  - D.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$

39. Which is the geometric isomer of *cis*-1,2-dichlorocyclopropane?



40. Which is the best-fit line or best-fit curve for the points plotted on the graph?

