

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

Monday 14 November 2016 (morning)

1 hour

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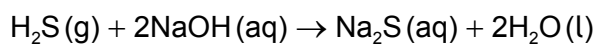
**Instructions to candidates**

- 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]**.

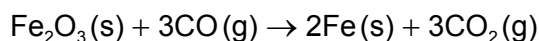
# The Periodic Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	1 <b>H</b> 1.01																	2 <b>He</b> 4.00	
2	3 <b>Li</b> 6.94	4 <b>Be</b> 9.01															8 <b>O</b> 16.00	9 <b>F</b> 19.00	10 <b>Ne</b> 20.18
3	11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31															16 <b>S</b> 32.07	17 <b>Cl</b> 35.45	18 <b>Ar</b> 39.95
4	19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.87	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> 58.69	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.38	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.63	33 <b>As</b> 74.92	34 <b>Se</b> 78.96	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.90	
5	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> 95.96	43 <b>Tc</b> (98)	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> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.29	
6	55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33	57† <b>La</b> 138.91	72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.84	75 <b>Re</b> 186.21	76 <b>Os</b> 190.23	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.08	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.38	82 <b>Pb</b> 207.2	83 <b>Bi</b> 208.98	84 <b>Po</b> (209)	85 <b>At</b> (210)	86 <b>Rn</b> (222)	
7	87 <b>Fr</b> (223)	88 <b>Ra</b> (226)	89‡ <b>Ac</b> (227)	104 <b>Rf</b> (267)	105 <b>Db</b> (268)	106 <b>Sg</b> (269)	107 <b>Bh</b> (270)	108 <b>Hs</b> (269)	109 <b>Mt</b> (278)	110 <b>Ds</b> (281)	111 <b>Rg</b> (281)	112 <b>Cn</b> (285)	113 <b>Unt</b> (286)	114 <b>Uug</b> (289)	115 <b>Uup</b> (288)	116 <b>Uuh</b> (293)	117 <b>Uus</b> (294)	118 <b>Uuo</b> (294)	
			†	58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> (145)	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.96	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	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> 173.05	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> (244)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (257)	101 <b>Md</b> (258)	102 <b>No</b> (259)	103 <b>Lr</b> (262)		

1. Which volume, in  $\text{cm}^3$ , of  $0.20 \text{ mol dm}^{-3}$   $\text{NaOH}(\text{aq})$  is needed to neutralize  $0.050 \text{ mol}$  of  $\text{H}_2\text{S}(\text{g})$ ?



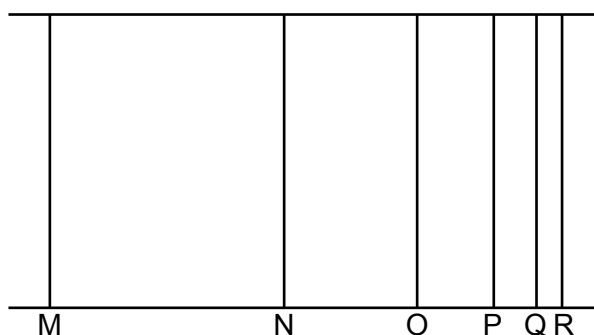
- A. 0.25
- B. 0.50
- C. 250
- D. 500
2. The complete combustion of  $15.0 \text{ cm}^3$  of a gaseous hydrocarbon **X** produces  $60.0 \text{ cm}^3$  of carbon dioxide gas and  $75.0 \text{ cm}^3$  of water vapour. What is the molecular formula of **X**? (All volumes are measured at the same temperature and pressure.)
- A.  $\text{C}_4\text{H}_6$
- B.  $\text{C}_4\text{H}_8$
- C.  $\text{C}_4\text{H}_{10}$
- D.  $\text{C}_6\text{H}_{10}$
3.  $5.0 \text{ mol}$  of  $\text{Fe}_2\text{O}_3(\text{s})$  and  $6.0 \text{ mol}$  of  $\text{CO}(\text{g})$  react according to the equation below. What is the limiting reactant and how many moles of the excess reactant remain unreacted?



	Limiting reactant	Moles of excess reactant remaining
A.	CO	2.0
B.	CO	3.0
C.	$\text{Fe}_2\text{O}_3$	1.0
D.	$\text{Fe}_2\text{O}_3$	2.0

Turn over

4. Which is correct for the line emission spectrum for hydrogen?



- A. Line M has a higher energy than line N.
- B. Line N has a lower frequency than line M.
- C. Line M has a longer wavelength than line N.
- D. Lines converge at lower energy.
5. Which representation would be correct for a species, **Z**, which has 31 protons, 40 neutrons and 28 electrons?
- A.  ${}_{31}^{71}\text{Z}^{3+}$
- B.  ${}_{31}^{71}\text{Z}^{3-}$
- C.  ${}_{40}^{71}\text{Z}^{3+}$
- D.  ${}_{28}^{71}\text{Z}^{3+}$
6. A period 3 element, **M**, forms an oxide of the type  $\text{M}_2\text{O}$ . Which represents the first four successive ionization energies of **M**?

Ionization energy / $\text{kJ mol}^{-1}$				
	First	Second	Third	Fourth
A.	496	4563	6913	9544
B.	738	1451	7733	10541
C.	578	1817	2745	11578
D.	787	1577	3232	4356

7. Which property increases down group 17, the halogens?
- A. Electron affinity
  - B. Boiling point
  - C. First ionization energy
  - D. Reactivity
8. Which correctly describes the reaction between potassium and excess water?
- A. The reaction is endothermic.
  - B. The final products of the reaction are potassium oxide and hydrogen.
  - C. The final products of the reaction are potassium hydroxide and hydrogen.
  - D. The final pH of the solution is 7.
9. The oxidation state of cobalt in the complex ion  $[\text{Co}(\text{NH}_3)_5\text{Br}]^x$  is +3. Which of the following statements are correct?
- I. The overall charge,  $x$ , of the complex ion is 2+.
  - II. The complex ion is octahedral.
  - III. The cobalt(III) ion has a half-filled d-subshell.
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III
10. What is the correct explanation for the colour of  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ ?
- A. Light is absorbed when an electron moves to a d orbital of higher energy.
  - B. Light is released when an electron moves to a d orbital of higher energy.
  - C. Light is absorbed when electrons move from the ligands to the central metal ion.
  - D. Light is absorbed when electrons move between d and s orbitals.

Turn over

11. How many electrons form the carbon–oxygen bond in methanal, HCHO?

- A. 2
- B. 4
- C. 8
- D. 12

12. Between which pair of molecules can hydrogen bonding occur?

- A. CH<sub>4</sub> and H<sub>2</sub>O
- B. CH<sub>3</sub>OCH<sub>3</sub> and CF<sub>4</sub>
- C. CH<sub>4</sub> and HF
- D. CH<sub>3</sub>OH and H<sub>2</sub>O

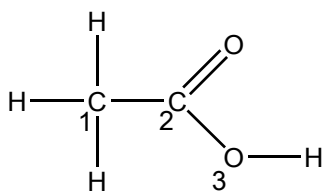
13. Which substance has a giant covalent structure?

	<b>Melting point / °C</b>	<b>Solubility in water</b>	<b>Electrical conductivity in the molten state</b>
A.	186	high	none
B.	801	high	good
C.	1083	low	good
D.	1710	low	none

14. Which species has bond angles of 90°?

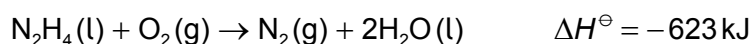
- A. AlCl<sub>4</sub><sup>-</sup>
- B. ICl<sub>4</sub><sup>-</sup>
- C. NH<sub>4</sub><sup>+</sup>
- D. SiCl<sub>4</sub>

15. What is the hybridization of the numbered atoms in ethanoic acid?



	Atom 1	Atom 2	Atom 3
A.	$sp^3$	$sp$	$sp^2$
B.	$sp^3$	$sp^2$	$sp$
C.	$sp^2$	$sp^3$	$sp^2$
D.	$sp^3$	$sp^2$	$sp^3$

16. Hydrazine reacts with oxygen.



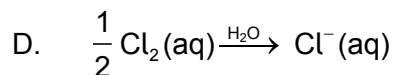
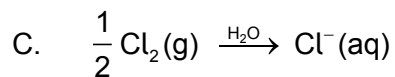
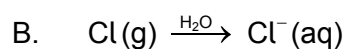
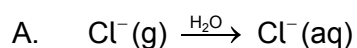
What is the standard enthalpy of formation of  $\text{N}_2\text{H}_4(\text{l})$  in kJ? The standard enthalpy of formation of  $\text{H}_2\text{O}(\text{l})$  is  $-286 \text{ kJ}$ .

- A.  $-623 - 286$   
 B.  $-623 + 572$   
 C.  $-572 + 623$   
 D.  $-286 + 623$
17. 5.35g of solid ammonium chloride,  $\text{NH}_4\text{Cl}(\text{s})$ , was added to water to form 25.0g of solution. The maximum decrease in temperature was 14 K. What is the enthalpy change, in  $\text{kJ mol}^{-1}$ , for this reaction? (Molar mass of  $\text{NH}_4\text{Cl} = 53.5 \text{ g mol}^{-1}$ ; the specific heat capacity of the solution is  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ )

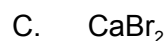
- A.  $\Delta H = + \frac{25.0 \times 4.18 \times (14 + 273)}{0.1 \times 1000}$   
 B.  $\Delta H = - \frac{25.0 \times 4.18 \times 14}{0.1 \times 1000}$   
 C.  $\Delta H = + \frac{25.0 \times 4.18 \times 14}{0.1 \times 1000}$   
 D.  $\Delta H = + \frac{25.0 \times 4.18 \times 14}{1000}$

Turn over

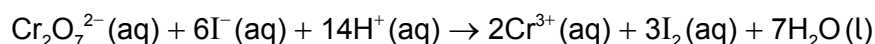
18. Which represents the enthalpy change of hydration of the chloride ion?



19. Which ionic compound has the largest value of lattice enthalpy?



20. Which experimental methods could be used to observe the progress of the following reaction?



- I. Change in colour
- II. Change in mass
- III. Change in electrical conductivity

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

21. Which statement describes the characteristics of a transition state relative to the potential energy of the reactants and products?

A. It is an unstable species with lower potential energy.

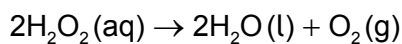
B. It is an unstable species with higher potential energy.

C. It is a stable species with lower potential energy.

D. It is a stable species with higher potential energy.



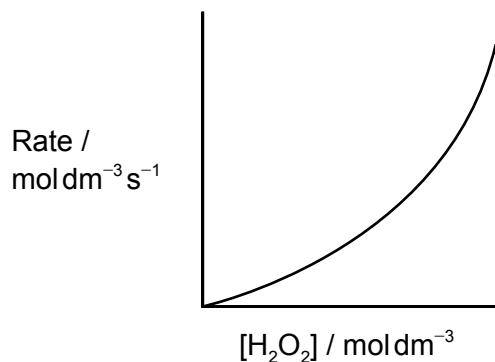
22. Decomposition of hydrogen peroxide in an aqueous solution proceeds as follows.



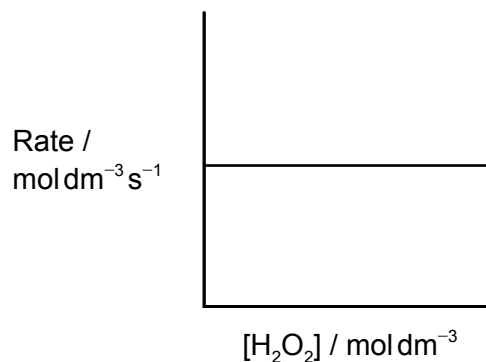
The rate expression for the reaction was found to be: rate =  $k[\text{H}_2\text{O}_2]$ .

Which graph is consistent with the given rate expression?

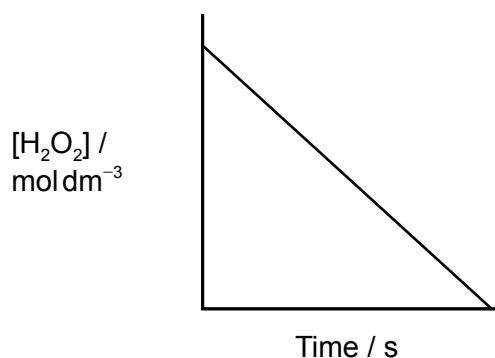
A.



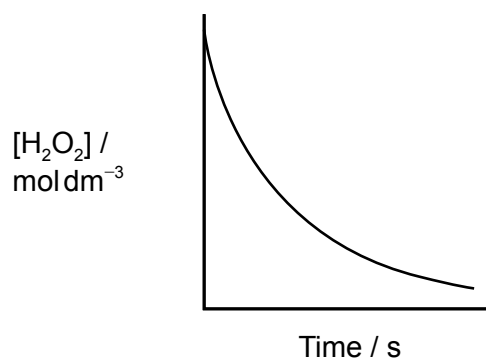
B.



C.



D.



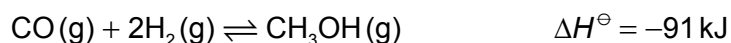
23. The rate constant,  $k$ , is commonly described by the Arrhenius equation:  $k = Ae^{\frac{-E_a}{RT}}$ . Which of the following statements are correct?

- I. A greater  $E_a$  value results in a smaller  $k$  value.
- II. Reactions of less complex molecules usually have a greater value of  $A$ .
- III. The slope (gradient) of  $\ln k$  versus  $\frac{1}{T}$  equals  $E_a$ .

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

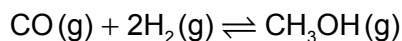
Turn over

24. What happens when the temperature of the following equilibrium system is increased?



	Position of equilibrium	Reaction rates of forward and reverse reactions
A.	shifts to the left	increase
B.	shifts to the left	decrease
C.	shifts to the right	decrease
D.	shifts to the right	increase

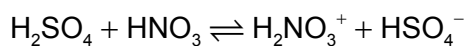
25. A mixture of 0.40 mol of CO(g) and 0.40 mol of H<sub>2</sub>(g) was placed in a 1.00 dm<sup>3</sup> vessel. The following equilibrium was established.



At equilibrium, the mixture contained 0.25 mol of CO(g). How many moles of H<sub>2</sub>(g) and CH<sub>3</sub>OH(g) were present at equilibrium?

	Equilibrium mol of H <sub>2</sub>	Equilibrium mol of CH <sub>3</sub> OH
A.	0.25	0.15
B.	0.50	0.25
C.	0.30	0.25
D.	0.10	0.15

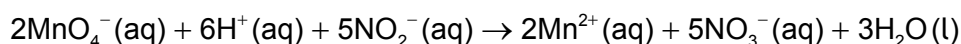
26. Which species behave as Brønsted–Lowry bases in the following reaction?



- A. HNO<sub>3</sub> and HSO<sub>4</sub><sup>-</sup>
- B. HNO<sub>3</sub> and H<sub>2</sub>NO<sub>3</sub><sup>+</sup>
- C. H<sub>2</sub>SO<sub>4</sub> and HSO<sub>4</sub><sup>-</sup>
- D. H<sub>2</sub>NO<sub>3</sub><sup>+</sup> and HSO<sub>4</sub><sup>-</sup>

27. What occurs when solid sodium hydrogen carbonate reacts with aqueous sulfuric acid?
- A. Bubbles of sulfur dioxide form.
  - B. Bubbles of both hydrogen and carbon dioxide form.
  - C. Bubbles of hydrogen form.
  - D. Bubbles of carbon dioxide form.
28. Which mixture is a buffer solution?
- A. 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> NH<sub>3</sub>(aq) and 50 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> HCl(aq)
  - B. 50 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> NH<sub>3</sub>(aq) and 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> HCl(aq)
  - C. 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> NaOH(aq) and 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> HCl(aq)
  - D. 50 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> NaOH(aq) and 25 cm<sup>3</sup> of 0.10 mol dm<sup>-3</sup> HCl(aq)
29. Which salt solution has the highest pH?
- A. NH<sub>4</sub>Cl
  - B. Ca(NO<sub>3</sub>)<sub>2</sub>
  - C. Na<sub>2</sub>CO<sub>3</sub>
  - D. K<sub>2</sub>SO<sub>4</sub>

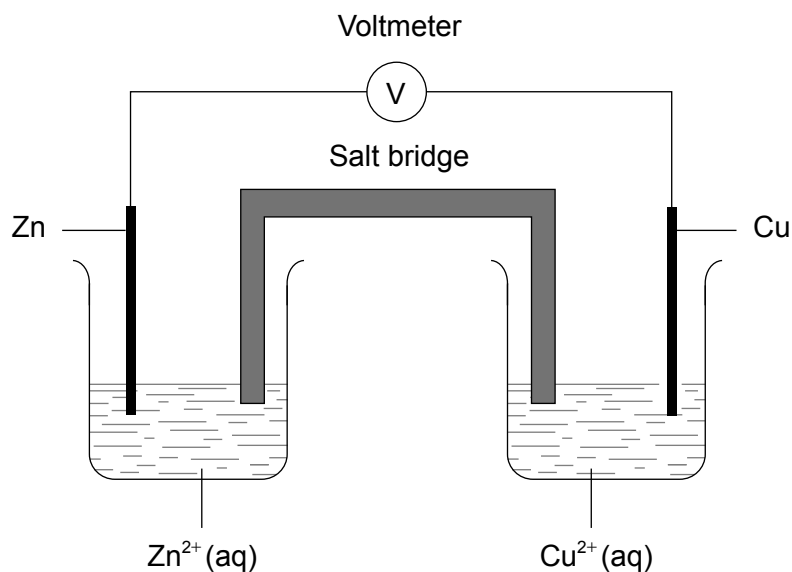
30. Which is a correct statement for the reaction below?



- A. MnO<sub>4</sub><sup>-</sup> is the reducing agent and the oxidation number of Mn increases.
- B. MnO<sub>4</sub><sup>-</sup> is the oxidizing agent and the oxidation number of Mn decreases.
- C. NO<sub>2</sub><sup>-</sup> is the reducing agent and the oxidation number of N decreases.
- D. NO<sub>2</sub><sup>-</sup> is the oxidizing agent and the oxidation number of N increases.

Turn over

31. A voltaic cell is constructed from zinc and copper half-cells. Zinc is more reactive than copper. Which statement is correct when this cell produces electricity?



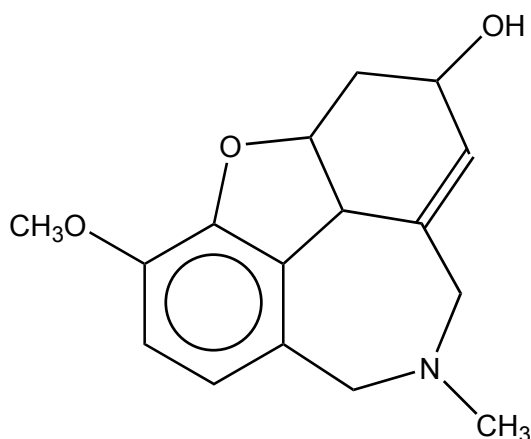
- A. Electrons flow from the copper half-cell to the zinc half-cell.
- B. The concentration of  $\text{Cu}^{2+}(\text{aq})$  increases.
- C. Electrons flow through the salt bridge.
- D. Negative ions flow through the salt bridge from the copper half-cell to the zinc half-cell.
32. Which signs for both  $E^{\ominus}_{\text{cell}}$  and  $\Delta G^{\ominus}$  result in a spontaneous redox reaction occurring under standard conditions?

	$E^{\ominus}_{\text{cell}}$	$\Delta G^{\ominus}$
A.	+	+
B.	-	+
C.	-	-
D.	+	-

33. An iron rod is electroplated with silver. Which is a correct condition for this process?

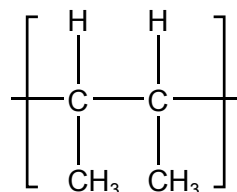
- A. The silver electrode is the positive electrode.
- B. The iron rod is the positive electrode.
- C. The electrolyte is iron(II) sulfate.
- D. Oxidation occurs at the negative electrode.

34. The structure of a drug used to treat symptoms of Alzheimer's disease is shown below. Which functional groups are present in this molecule?



- A. Hydroxyl and ester
- B. Hydroxide and ether
- C. Hydroxyl and ether
- D. Hydroxide and ester

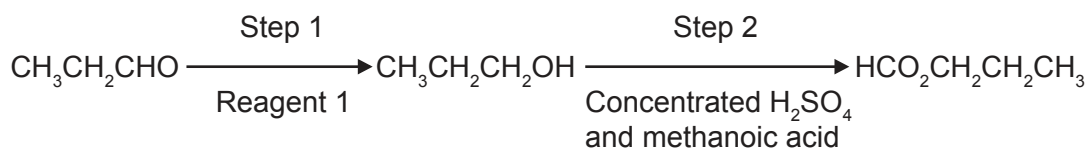
35. Which monomer is used to form the polymer with the following repeating unit?



- A.  $\text{CH}_3\text{CH}=\text{CHCH}_3$
- B.  $\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$
- C.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$
- D.  $(\text{CH}_3)_2\text{C}=\text{CH}_2$

Turn over

36. Which is correct for the conversion of propanal to propyl methanoate?



	Reagent for step 1	Reaction type in step 1	Reaction type in step 2
A.	H <sub>2</sub> O	hydration	addition
B.	K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> , dilute H <sub>2</sub> SO <sub>4</sub>	oxidation	nucleophilic substitution (condensation)
C.	NaBH <sub>4</sub>	reduction	oxidation
D.	NaBH <sub>4</sub>	reduction	nucleophilic substitution (condensation)

37. Which statement is correct for a pair of enantiomers under the same conditions?

- A. A racemic mixture of the enantiomers is optically active.
- B. They have the same chemical properties in all their reactions.
- C. They have the same melting and boiling points.
- D. They rotate the plane of plane-polarized light by different angles.

38. A student carried out a titration to determine the concentration of an acid and found that his value had good precision but poor accuracy. Which process explains this outcome?

- A. Consistently overshooting the volume of solution from the burette into the flask.
- B. Collection of insufficient titration data.
- C. Reading the meniscus in the burette at a different angle each time.
- D. Forgetting to rinse the flask after one of the titrations.

39. What is always correct about the molecular ion,  $M^+$ , in a mass spectrum of a compound?
- A. The  $M^+$  ion peak has the smallest  $m/z$  ratio in the mass spectrum.
  - B. The  $m/z$  ratio of the  $M^+$  ion peak gives the relative molecular mass of the molecule.
  - C. The  $M^+$  ion is the most stable fragment formed during electron bombardment.
  - D. The  $M^+$  ion peak has the greatest intensity in the mass spectrum.
40. Which property explains why tetramethylsilane,  $\text{Si}(\text{CH}_3)_4$ , can be used as a reference standard in  $^1\text{H}$ NMR spectroscopy?
- A. It has a high boiling point.
  - B. It is a reactive compound.
  - C. All its protons are in the same chemical environment.
  - D. It gives multiple signals.
-