

No part of this product may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without written permission from the IB.

Additionally, the license tied with this product prohibits commercial use of any selected files or extracts from this product. Use by third parties, including but not limited to publishers, private teachers, tutoring or study services, preparatory schools, vendors operating curriculum mapping services or teacher resource digital platforms and app developers, is not permitted and is subject to the IB's prior written consent via a license. More information on how to request a license can be obtained from <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

Aucune partie de ce produit ne peut être reproduite sous quelque forme ni par quelque moyen que ce soit, électronique ou mécanique, y compris des systèmes de stockage et de récupération d'informations, sans l'autorisation écrite de l'IB.

De plus, la licence associée à ce produit interdit toute utilisation commerciale de tout fichier ou extrait sélectionné dans ce produit. L'utilisation par des tiers, y compris, sans toutefois s'y limiter, des éditeurs, des professeurs particuliers, des services de tutorat ou d'aide aux études, des établissements de préparation à l'enseignement supérieur, des fournisseurs de services de planification des programmes d'études, des gestionnaires de plateformes pédagogiques en ligne, et des développeurs d'applications, n'est pas autorisée et est soumise au consentement écrit préalable de l'IB par l'intermédiaire d'une licence. Pour plus d'informations sur la procédure à suivre pour demander une licence, rendez-vous à l'adresse suivante : <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

No se podrá reproducir ninguna parte de este producto de ninguna forma ni por ningún medio electrónico o mecánico, incluidos los sistemas de almacenamiento y recuperación de información, sin que medie la autorización escrita del IB.

Además, la licencia vinculada a este producto prohíbe el uso con fines comerciales de todo archivo o fragmento seleccionado de este producto. El uso por parte de terceros —lo que incluye, a título enunciativo, editoriales, profesores particulares, servicios de apoyo académico o ayuda para el estudio, colegios preparatorios, desarrolladores de aplicaciones y entidades que presten servicios de planificación curricular u ofrezcan recursos para docentes mediante plataformas digitales— no está permitido y estará sujeto al otorgamiento previo de una licencia escrita por parte del IB. En este enlace encontrará más información sobre cómo solicitar una licencia: <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

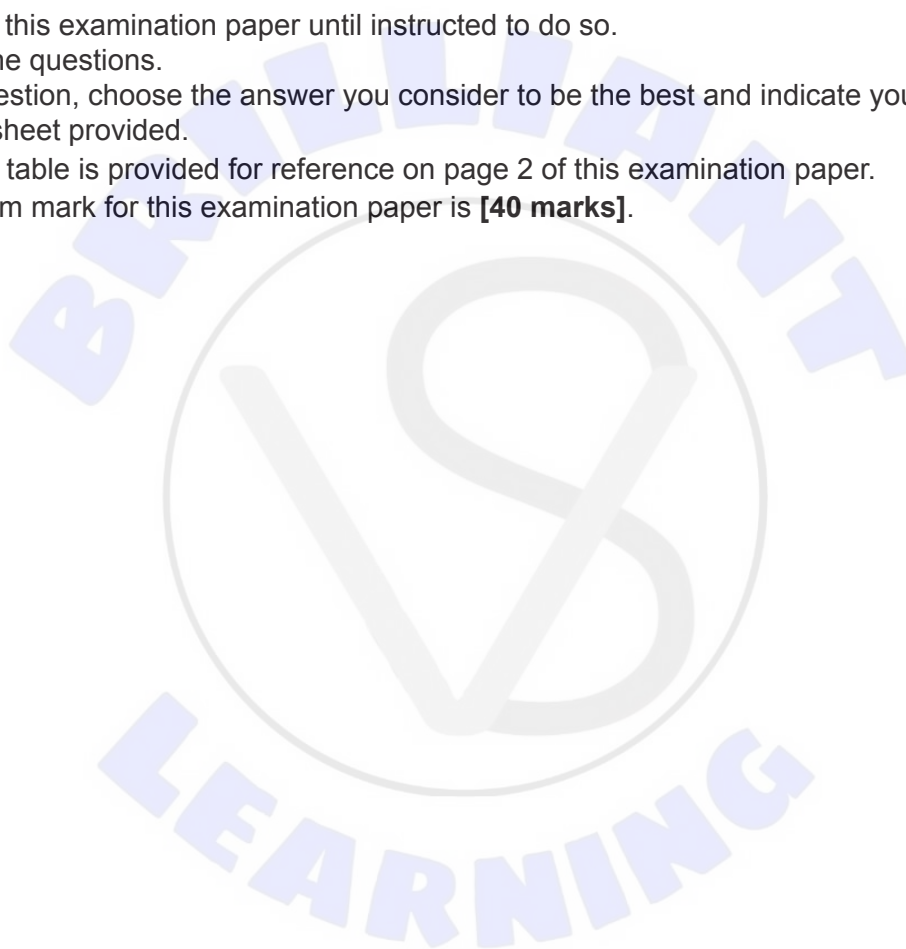
Chemistry
Higher level
Paper 1

Thursday 5 November 2020 (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																		2 He 4.00		
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)			

Atomic number

Element

Relative atomic mass

†

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
---------------------------	---------------------------	---------------------------	--------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------	---------------------------

‡

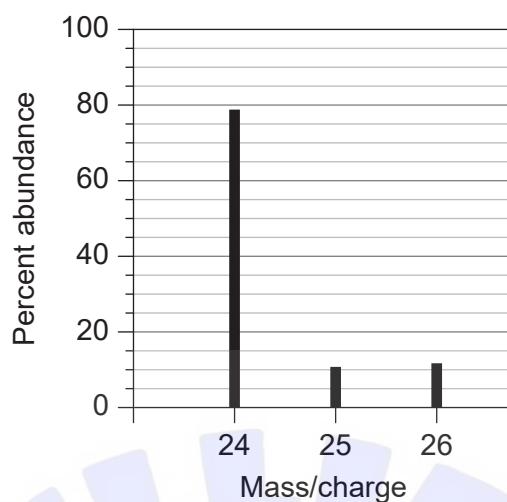
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)
---------------------------	---------------------------	--------------------------	--------------------------	--------------------------	--------------------------	--------------------------	--------------------------	--------------------------	--------------------------	---------------------------	---------------------------	---------------------------	---------------------------

1. What is the number of carbon atoms in 12g of ethanoic acid CH_3COOH , $M_r = 60$?
- A. 0.20
B. 2.0
C. 1.2×10^{23}
D. 2.4×10^{23}
2. Which of these molecular formulae are also empirical formulae?
- I. $\text{C}_2\text{H}_6\text{O}$
II. $\text{C}_2\text{H}_4\text{O}_2$
III. C_5H_{12}
- A. I and II only
B. I and III only
C. II and III only
D. I, II and III
3. Which volume of ethane gas, in cm^3 , will produce 40 cm^3 of carbon dioxide gas when mixed with 140 cm^3 of oxygen gas, assuming the reaction goes to completion?



- A. 10
B. 20
C. 40
D. 80

4. What is the relative atomic mass, A_r , of an element with this mass spectrum?



- A. 24.0
 B. 24.3
 C. 24.9
 D. 25.0
5. Which element is in group 13?

Ionization energy / kJ mol^{-1}				
	1st	2nd	3rd	4th
A.	789	1580	3230	4360
B.	578	1820	2750	11 600
C.	738	1450	7730	10 500
D.	496	4560	6910	9540

6. What is the correct trend going down groups 1 and 17?
- A. Melting points increase
 B. Boiling points decrease
 C. Electronegativities increase
 D. Ionization energies decrease

7. Which oxide will dissolve in water to give the solution with the lowest pH?
- A. P_4O_{10}
 - B. SiO_2
 - C. Al_2O_3
 - D. MgO
8. Which of these statements are correct?
- I. Zinc is **not** a transition element.
 - II. Ligands are Lewis bases.
 - III. Manganese(II) chloride is paramagnetic.
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III
9. Which of these species contains the shortest carbon to oxygen bond length?
- A. $CH_3CH_2O^-$
 - B. CH_3CH_2OH
 - C. CH_3COO^-
 - D. CH_3COOH
10. Which molecule is most polar?
- A. CHF_3
 - B. CF_4
 - C. $CClF_3$
 - D. CCl_4

Turn over

11. Which combination correctly describes the geometry of BrF_4^- ?

	Electron domain geometry around Br	Molecular geometry around Br
A.	Octahedral	Tetrahedral
B.	Tetrahedral	Square planar
C.	Octahedral	Square planar
D.	Tetrahedral	Tetrahedral

12. Which series shows the correct order of metallic bond strength from strongest to weakest?

- A. $\text{Na} > \text{K} > \text{Rb} > \text{Mg}$
- B. $\text{Mg} > \text{Rb} > \text{K} > \text{Na}$
- C. $\text{Rb} > \text{K} > \text{Na} > \text{Mg}$
- D. $\text{Mg} > \text{Na} > \text{K} > \text{Rb}$

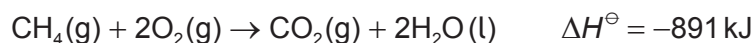
13. Which statement is correct?

- A. O_3 bond dissociation occurs at a longer wavelength of light than O_2 bond dissociation.
- B. O_3 bond dissociation occurs at a higher energy than O_2 bond dissociation.
- C. O_3 bond lengths are shorter than O_2 bond lengths.
- D. O_3 bond dissociation occurs at a higher frequency of light than O_2 bond dissociation.

14. Which equation shows the enthalpy of formation, ΔH_f° , of ethanol?

- A. $2\text{C}(\text{s}) + 3\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{C}_2\text{H}_5\text{OH}(\text{g})$
- B. $4\text{C}(\text{s}) + 6\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{C}_2\text{H}_5\text{OH}(\text{g})$
- C. $2\text{C}(\text{s}) + 3\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{C}_2\text{H}_5\text{OH}(\text{l})$
- D. $4\text{C}(\text{s}) + 6\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{C}_2\text{H}_5\text{OH}(\text{l})$

15. Which statements about bond strength and activation energy are correct for this reaction?



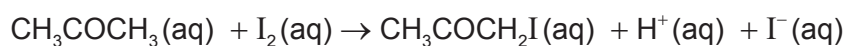
	Relative bond strength	Relative magnitude of activation energy, E_a
A.	products < reactants	forward > reverse
B.	products > reactants	forward < reverse
C.	products > reactants	forward > reverse
D.	products < reactants	forward < reverse

16. Which combination gives the standard hydration enthalpy of $\text{Na}^+(\text{g})$?

	kJ mol^{-1}
ΔH^\ominus lattice $\text{NaCl}(\text{s})$	+790
ΔH^\ominus solution $\text{NaCl}(\text{s})$	+4
ΔH^\ominus hydration $\text{Cl}^-(\text{g})$	-359

- A. $4 + 359 + 790$
- B. $4 + 359 - 790$
- C. $-4 - 359 + 790$
- D. $4 - 359 + 790$
17. Which reaction becomes more spontaneous as temperature increases?
- A. $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- B. $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
- C. $3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g}) \rightarrow \text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g})$
- D. $\text{SO}_2(\text{g}) + \text{H}_2\text{O}_2(\text{l}) \rightarrow \text{H}_2\text{SO}_4(\text{l})$

18. Which apparatus can be used to monitor the rate of this reaction?



- I. A pH meter
- II. A gas syringe
- III. A colorimeter

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

19. Which change does **not** increase the rate of this reaction?

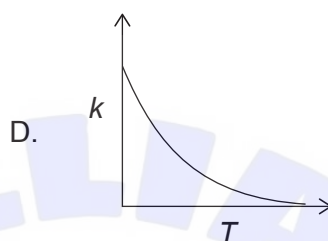
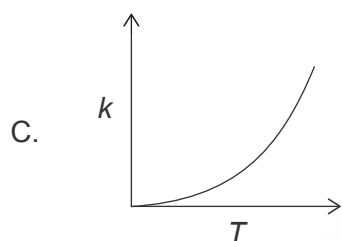
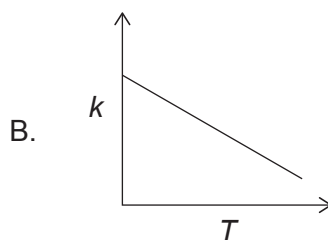
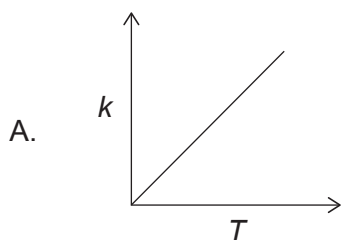


- A. Increasing the particle size of the CuCO_3
- B. Increasing the temperature
- C. Increasing the concentration of $\text{H}_2\text{SO}_4(\text{aq})$
- D. Stirring the reaction mixture

20. What are the units of the rate constant, k , if the rate equation is $\text{Rate} = k[\text{A}][\text{B}]^2$?

- A. $\text{mol dm}^{-3} \text{s}^{-1}$
- B. $\text{dm}^3 \text{mol}^{-1} \text{s}^{-1}$
- C. $\text{dm}^6 \text{mol}^{-2} \text{s}^{-1}$
- D. $\text{dm}^9 \text{mol}^{-3} \text{s}^{-1}$

21. Which graph represents the relationship between the rate constant, k , and temperature, T , in kelvin?



22. What is correct when temperature increases in this reaction at equilibrium?



	Position of equilibrium	Equilibrium constant, K_c
A.	Shifts left	Unchanged
B.	Shifts left	Decreases
C.	Shifts right	Unchanged
D.	Shifts right	Increases

23. Which statement is correct for a spontaneous reaction?

	ΔG^\ominus	K_c
A.	negative	>1
B.	negative	<1
C.	positive	<1
D.	positive	>1

24. Which of these oxides contribute to acid deposition?

- I. SO_2
- II. NO_2
- III. CO_2

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

25. Which of these acids has the weakest conjugate base?

- A. HCl
- B. CH_3COOH
- C. NH_4Cl
- D. $\text{C}_6\text{H}_5\text{COOH}$

26. Which species is a Lewis acid but **not** a Brønsted–Lowry acid?

- A. Cu^{2+}
- B. NH_4^+
- C. Cu
- D. CH_3COOH

27. What is the pH of an ammonia solution that has $[\text{OH}^-] = 1 \times 10^{-4} \text{ mol dm}^{-3}$?

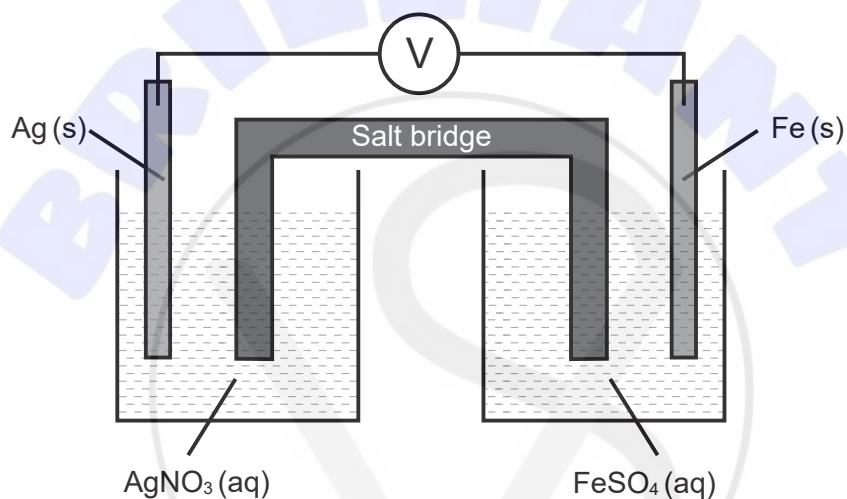
- A. 4.0
- B. 8.0
- C. 10.0
- D. 12.0

28. What are the oxidation states of oxygen?

	O_2	OF_2	H_2O_2
A.	-2	-2	-2
B.	0	-2	-1
C.	0	+2	-1
D.	-2	+2	-2

29. Iron is a stronger reducing agent than silver.

What is correct when this voltaic cell is in operation?



	Anode (negative electrode)	Cathode (positive electrode)	Direction of electron flow in wire
A.	Ag	Fe	right to left
B.	Ag	Fe	left to right
C.	Fe	Ag	left to right
D.	Fe	Ag	right to left

Turn over

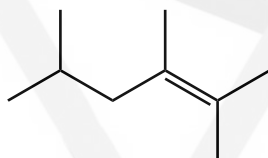
30. Which conditions deposit the greatest mass of copper when solutions containing copper ions are electrolysed for 10 minutes?

	Current / A	Ionic charge on copper ion
A.	5.0	2+
B.	2.5	2+
C.	2.5	1+
D.	5.0	1+

31. Which statement is correct when a zinc spoon is electroplated with silver?

- A. The cathode (negative electrode) is made of silver.
 B. The anode (positive electrode) is the zinc spoon.
 C. The anode (positive electrode) is made of silver.
 D. The electrolyte is zinc sulfate solution.

32. What is the IUPAC name of this molecule?



- A. 1,1,2,4-tetramethylpent-1-ene
 B. 2,4,5-trimethylhex-4-ene
 C. 2,4,5,5-tetramethylpent-4-ene
 D. 2,3,5-trimethylhex-2-ene
33. Which molecule will decolorize bromine water in the dark?
- A. cyclohexane
 B. hexane
 C. hex-1-ene
 D. hexan-1-ol

34. Which molecule can be oxidized to a carboxylic acid by acidified potassium dichromate(VI)?
- A. Propan-1-ol
 - B. Propan-2-ol
 - C. 2-methylpropan-2-ol
 - D. Propanone
35. Which is the electrophile in the nitration of benzene?
- A. HNO_3
 - B. NO_2^+
 - C. NO_2^-
 - D. NH_4^+
36. What will be the major product in the reaction between but-1-ene and HBr?
- A. 2-bromobut-1-ene
 - B. 1-bromobut-1-ene
 - C. 2-bromobutane
 - D. 1-bromobutane
37. Which molecule has an enantiomer?
- A. $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$
 - B. $\text{CH}_2(\text{OH})\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$
 - C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}=\text{CHBr}$
 - D. $\text{CH}_3\text{CHBrCH}_2\text{CH}_2\text{CH}_3$

Turn over

38. A student obtained the following data to calculate q , using $q = mc\Delta T$.

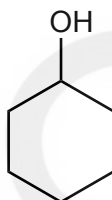
$$m = 20.0\text{g} \pm 0.2\text{g}$$

$$\Delta T = 10^\circ\text{C} \pm 1^\circ\text{C}$$

$$c = 4.18\text{J g}^{-1}\text{K}^{-1}$$

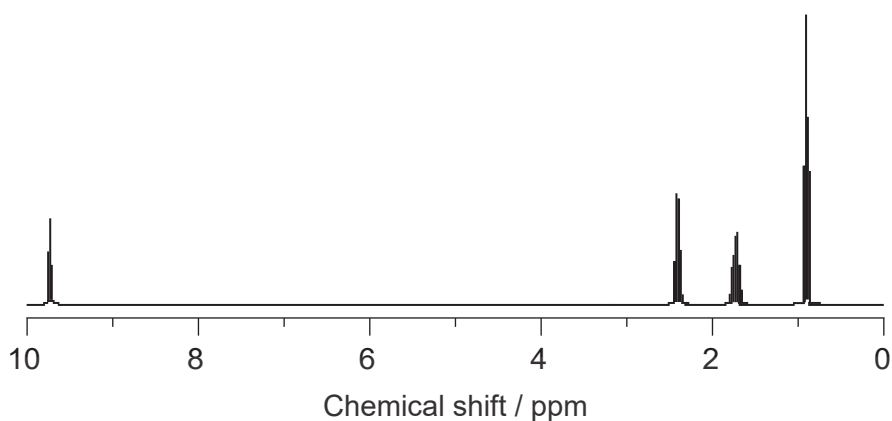
What is the percentage uncertainty in the calculated value of q ?

- A. 0.2
 - B. 1.2
 - C. 11
 - D. 14
39. What is the index of hydrogen deficiency (IHD) in cyclohexanol?



- A. 0
- B. 1
- C. 2
- D. 3

40. Which compound with the molecular formula C_4H_8O has this high resolution 1H NMR?



- A. but-3-en-2-ol, $CH_2=CHCH(OH)CH_3$
- B. butanal, $CH_3CH_2CH_2CHO$
- C. butanone, $CH_3COCH_2CH_3$
- D. but-3-en-1-ol, $CH_2=CHCH_2CH_2OH$



References:

40. From: libretexts.org. Courtesy of Chris Schaller, Professor (Chemistry) at College of Saint Benedict/Saint John's University.