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# Chemistry

## Higher level

### Paper 1

Thursday 5 November 2020 (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      8      9      10      11      12      13      14      15      16      17      18

		Atomic number																2		
		Element																		
		Relative atomic mass																		
1	1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		H	Li	Be	B	C	N	O	F	Ne										He
		1.01	6.94	9.01	12.01	14.01	16.00	19.00	20.18										4.00	
2	3	11	12	13	14	15	16	17	18											
		Na	Mg	Al	Si	P	S	Cl	Ar											
		22.99	24.31	26.98	28.09	30.97	32.07	35.45	39.95											
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		
		K	Ca	Sc	Ti	V	Cr	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
		39.10	40.08	44.96	47.87	50.94	52.00	55.85	58.93	58.69	63.55	65.38	69.72	72.63	74.92	78.96	79.90	83.90		
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54		
		Rb	Sr	Y	Zr	Nb	Mo	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
		85.47	87.62	88.91	91.22	92.91	95.96	101.07	102.91	106.42	107.87	112.41	114.82	118.71	121.76	127.60	126.90	131.29		
6	55	56	57 †	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86		
		Cs	Ba	La	Hf	Ta	W	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
		132.91	137.33	138.91	178.49	180.95	183.84	190.23	192.22	195.08	196.97	200.59	204.38	207.2	208.98	(209)	(210)	(222)		
7	87	88	89 ‡	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118		
		Fr	Ra	Ac	Rf	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Uug	Uup	Uuh	Uus	Uuo		
		(223)	(226)	(227)	(267)	(268)	(270)	(269)	(278)	(281)	(281)	(285)	(286)	(289)	(288)	(293)	(294)	(294)		

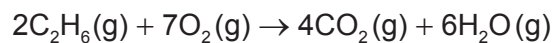
†

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
140.12	140.91	144.24	(145)	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.05	174.97

‡

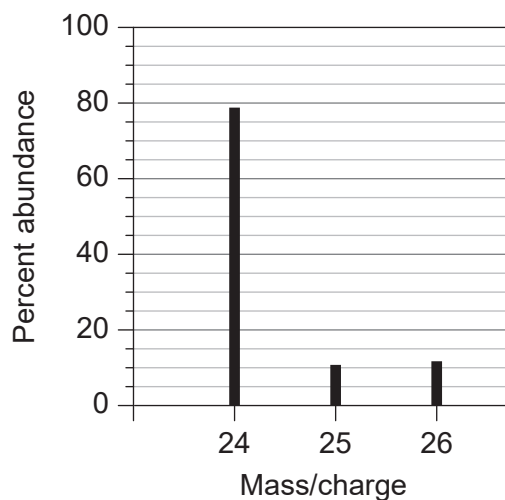
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
232.04	231.04	238.03	(237)	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)	(262)

1. What is the number of carbon atoms in 12g of ethanoic acid  $\text{CH}_3\text{COOH}$ ,  $M_r = 60$ ?
- A. 0.20  
B. 2.0  
C.  $1.2 \times 10^{23}$   
D.  $2.4 \times 10^{23}$
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.  $\text{C}_5\text{H}_{12}$
- 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  $\text{cm}^3$ , will produce  $40\text{cm}^3$  of carbon dioxide gas when mixed with  $140\text{cm}^3$  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 / $\text{kJ mol}^{-1}$				
	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.  $CCl_4$

11. Which combination correctly describes the geometry of  $\text{BrF}_4^-$ ?

	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.  $\text{Mg} > \text{Na} > \text{K} > \text{Rb}$

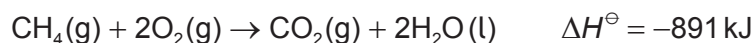
13. Which statement is correct?

- A.  $\text{O}_3$  bond dissociation occurs at a longer wavelength of light than  $\text{O}_2$  bond dissociation.
- B.  $\text{O}_3$  bond dissociation occurs at a higher energy than  $\text{O}_2$  bond dissociation.
- C.  $\text{O}_3$  bond lengths are shorter than  $\text{O}_2$  bond lengths.
- D.  $\text{O}_3$  bond dissociation occurs at a higher frequency of light than  $\text{O}_2$  bond dissociation.

14. Which equation shows the enthalpy of formation,  $\Delta H_f^\circ$ , 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

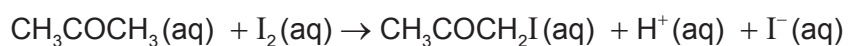
16. Which combination gives the standard hydration enthalpy of  $\text{Na}^+(\text{g})$ ?

	$\text{kJ mol}^{-1}$
$\Delta H^\ominus$ lattice $\text{NaCl}(\text{s})$	+790
$\Delta H^\ominus$ solution $\text{NaCl}(\text{s})$	+4
$\Delta H^\ominus$ 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.  $\text{SO}_2(\text{g}) + \text{H}_2\text{O}_2(\text{l}) \rightarrow \text{H}_2\text{SO}_4(\text{l})$



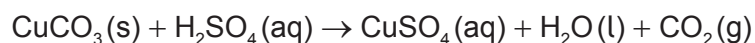
18. Which apparatus can be used to monitor the rate of this reaction?



- 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?

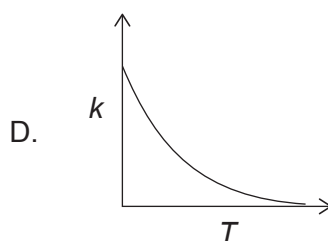
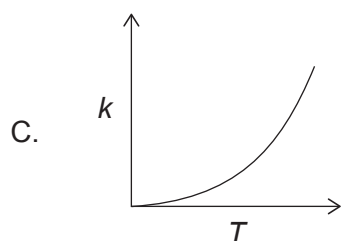
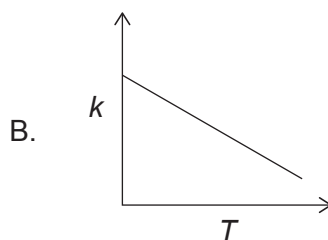
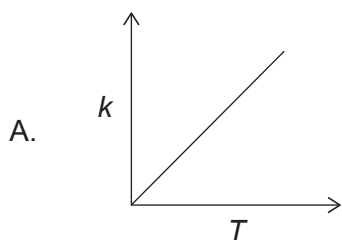


- A. Increasing the particle size of the  $\text{CuCO}_3$
- B. Increasing the temperature
- C. Increasing the concentration of  $\text{H}_2\text{SO}_4(\text{aq})$
- D. Stirring the reaction mixture

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?

	$\Delta G^\ominus$	$K_c$
A.	negative	$>1$
B.	negative	$<1$
C.	positive	$<1$
D.	positive	$>1$

24. Which of these oxides contribute to acid deposition?

- I.  $\text{SO}_2$
- II.  $\text{NO}_2$
- III.  $\text{CO}_2$

- 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.  $\text{HCl}$
- B.  $\text{CH}_3\text{COOH}$
- C.  $\text{NH}_4\text{Cl}$
- D.  $\text{C}_6\text{H}_5\text{COOH}$

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

- A.  $\text{Cu}^{2+}$
- B.  $\text{NH}_4^+$
- C.  $\text{Cu}$
- D.  $\text{CH}_3\text{COOH}$

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

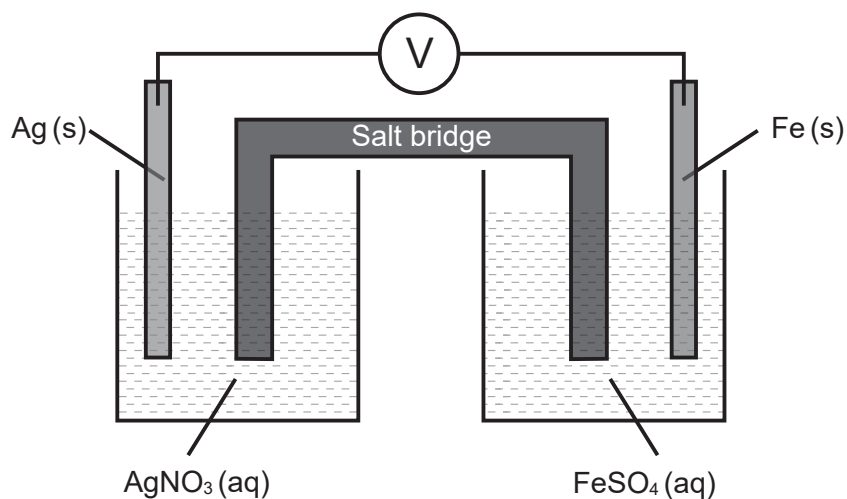
- A. 4.0
- B. 8.0
- C. 10.0
- D. 12.0

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?



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

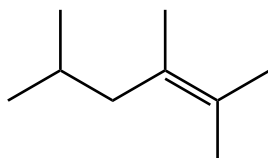
30. Which conditions deposit the greatest mass of copper when solutions containing copper ions are electrolysed for 10 minutes?

	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.  $\text{HNO}_3$
  - B.  $\text{NO}_2^+$
  - C.  $\text{NO}_2^-$
  - D.  $\text{NH}_4^+$
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.  $\text{CH}_3\text{CHBrCH}_2\text{CH}_2\text{CH}_3$

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

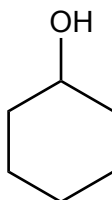
$$m = 20.0\text{g} \pm 0.2\text{g}$$

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

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

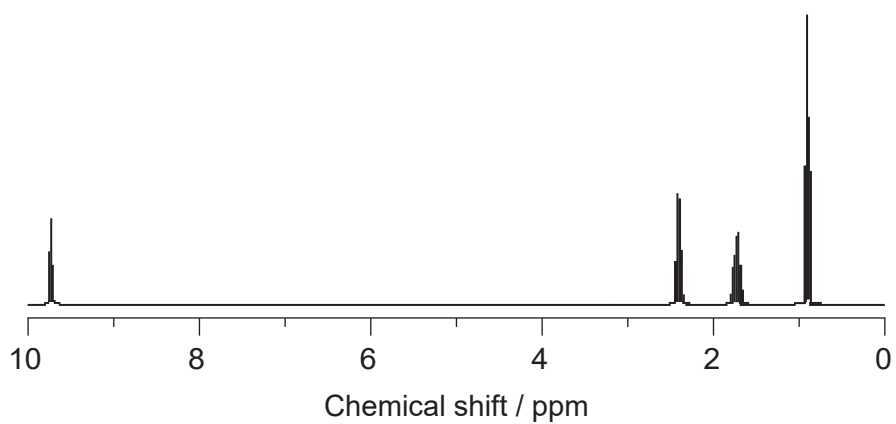
What is the percentage uncertainty in the calculated value of  $q$ ?

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