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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 | | | | | | | | | | | | | | | 8 O 16.00 | 9 F 19.00 | 10 Ne 20.18 |
| 3 | 11 Na 22.99 | 12 Mg 24.31 | | | | | | | | | | | | | | | 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) | |

| |
|----------------------|
| Atomic number |
| Element |
| Relative atomic mass |

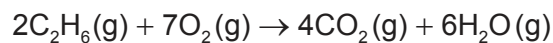
†

| | | | | | | | | | | | | | |
|---------------------------|---------------------------|---------------------------|--------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| 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) |
|---------------------------|---------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------------|---------------------------|---------------------------|---------------------------|

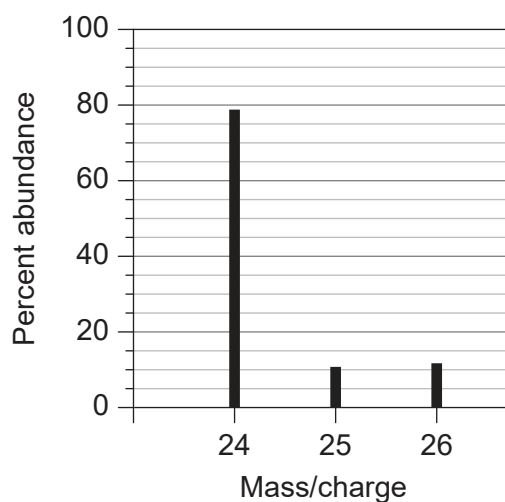
1. What is the number of carbon atoms in 12g of ethanoic acid CH_3COOH , $M_r = 60$?
- A. 0.20
B. 2.0
C. 1.2×10^{23}
D. 2.4×10^{23}
2. Which of these molecular formulae are also empirical formulae?
- I. $\text{C}_2\text{H}_6\text{O}$
II. $\text{C}_2\text{H}_4\text{O}_2$
III. C_5H_{12}
- A. I and II only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



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

Turn over

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

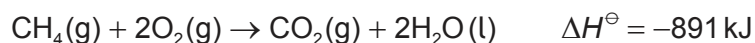
13. Which statement is correct?

- 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 |

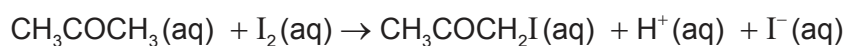
16. Which combination gives the standard hydration enthalpy of $\text{Na}^+(\text{g})$?

| | 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. $\text{SO}_2(\text{g}) + \text{H}_2\text{O}_2(\text{l}) \rightarrow \text{H}_2\text{SO}_4(\text{l})$

Turn over

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?

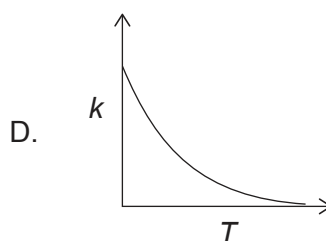
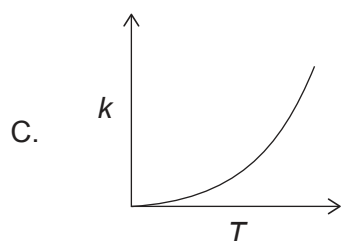
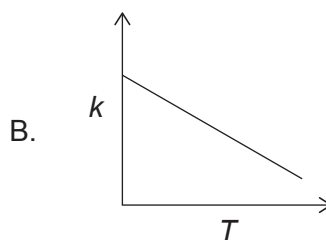
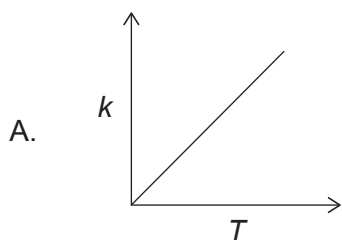


- A. Increasing the particle size of the CuCO_3
- B. Increasing the temperature
- C. Increasing the concentration of $\text{H}_2\text{SO}_4(\text{aq})$
- D. Stirring the reaction mixture

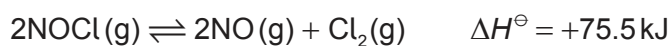
20. What are the units of the rate constant, k , if the rate equation is $\text{Rate} = k[\text{A}][\text{B}]^2$?

- 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 $[\text{OH}^-] = 1 \times 10^{-4} \text{ mol dm}^{-3}$?

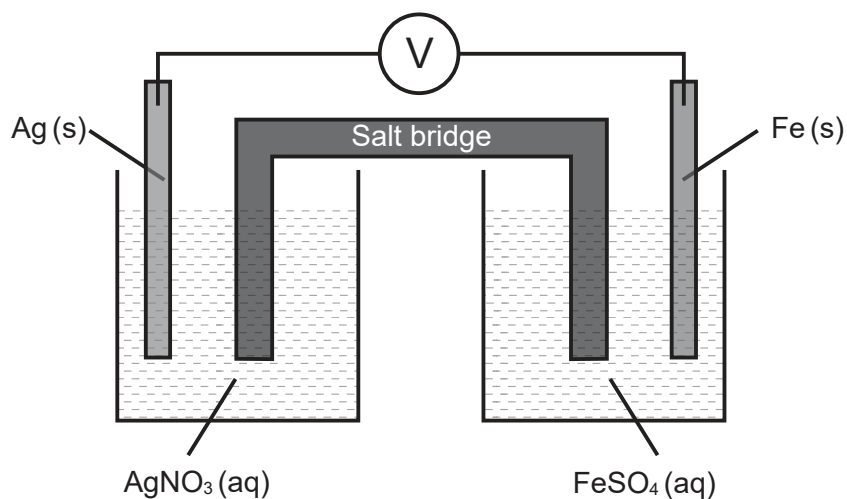
- A. 4.0
- B. 8.0
- C. 10.0
- D. 12.0

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

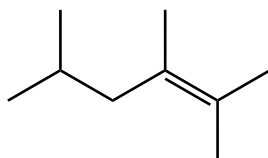
30. Which conditions deposit the greatest mass of copper when solutions containing copper ions are electrolysed for 10 minutes?

| | 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 $q = mc\Delta T$.

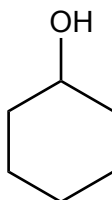
$$m = 20.0\text{g} \pm 0.2\text{g}$$

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

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

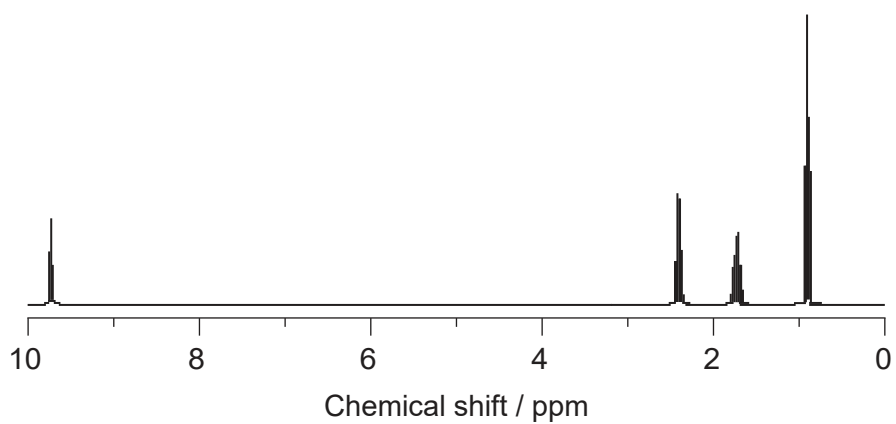
What is the percentage uncertainty in the calculated value of q ?

- 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.