



New Zealand Chemistry Olympiad Trust

Training Group Selection Examination

September 2023

40 Multichoice questions

TIME ALLOWED: 60 minutes

Calculators may be used.

A periodic table with atomic masses may be provided by the school

1. Which molecule has a shape most similar to the NH_3 molecule?
- A. GaI_3 B. PBr_3 C. FeCl_3 D. SOCl_2 E. BF_3
2. Which of the following shows the order in which molecules have an increasing bond angle to the central atom?
- A. $\text{CH}_4, \text{NH}_3, \text{H}_2\text{O}$ B. $\text{NH}_3, \text{H}_2\text{O}, \text{CH}_4$
 C. $\text{NH}_3, \text{CH}_4, \text{H}_2\text{O}$ D. $\text{H}_2\text{O}, \text{NH}_3, \text{CH}_4$
 E. $\text{H}_2\text{O}, \text{CH}_4, \text{NH}_3$

3. What is the minimum mass in grams of O_2 ($M = 32 \text{ g mol}^{-1}$) required to burn 1.6 g of CH_4 ($M = 16 \text{ g mol}^{-1}$) according to the equation below?



- A. 1.6 B. 3.2 C. 6.4 D. 32 E. 64
4. A partially balanced equation for the conversion of sulfur dioxide to sulfuric acid is given below.



Which other species are required to balance the equation, and on which side of the equation do they appear?

- A. H^+ and e^- on the right. B. H^+ on the left and e^- on the right.
 C. H^+ on the right and e^- on the left. D. H^+ and e^- on the left.
 E. Only e^- on the right.
5. Which is the conjugate acid of glycine (aminoethanoic acid)?
- A. H_3O^+ B. $\text{H}_2\text{N}-\text{CH}_2-\text{COOH}$ C. $\text{H}_3\text{N}^+-\text{CH}_2-\text{COOH}$
 D. $\text{H}_2\text{N}-\text{CH}_2-\text{CO}_2^-$ E. $\text{H}_3\text{N}^+-\text{CH}_2-\text{COO}^-$
6. A metal M displaces copper from aqueous copper(II) sulfate but does not react with aqueous zinc nitrate. Which list gives the metals in order of increasing strength as reducing agents?
- A. $\text{Cu} < \text{Zn} < \text{M}$ B. $\text{Cu} < \text{M} < \text{Zn}$ C. $\text{Zn} < \text{M} < \text{Cu}$
 D. $\text{M} < \text{Cu} < \text{Zn}$ E. $\text{Zn} < \text{Cu} < \text{M}$

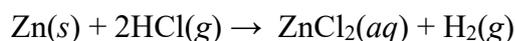
7. Which equation represents an oxidation-reduction reaction?

- A. $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$
- B. $\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}$
- C. $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$
- D. $(\text{CH}_3)_2\text{CHCl} + \text{OH}^- \rightarrow (\text{CH}_3)_2\text{CHOH} + \text{Cl}^-$
- E. $\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$

8. Which statement comparing catalytic reactions to non-catalytic reactions is correct?

- A. The activation energy of the catalytic reaction is smaller.
- B. The activation energy of the catalytic reaction is larger.
- C. Either the reactants or the products of the catalytic reaction are different.
- D. The enthalpy of reaction of the catalytic reaction is smaller.
- E. The enthalpy of reaction of the catalytic reaction is larger.

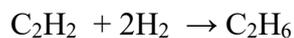
9. Some students have been measuring the rate of reaction between 5.0 g of zinc granules and 100 mL of 1.0 mol L⁻¹ HCl at room temperature. The equation for the reaction is:



Which change to the procedure would probably NOT increase the rate of reaction?

- A. Warming the HCl before adding the zinc.
- B. Using zinc powder instead of zinc granules.
- C. Using 50 mL of 2.0 mol L⁻¹ HCl.
- D. Using 200 mL of 1.0 mol L⁻¹ HCl.
- E. Using 100 mL of 1.0 mol L⁻¹ H₂SO₄.

10. Acetylene (HC≡CH) reacts with H₂ as shown below.



Calculate the heat released (in kJ mol⁻¹) during this reaction, using the bond enthalpies given.

C-H 413 C-C 347 C=C 614 C≡C 839 H-H 432

- A. 1160 B. 788 C. 563 D. 521 E. 296

11. The average bond enthalpy for the C-H bond is 413 kJ mol^{-1} . Which reaction has an enthalpy change closest to this value?

- A. $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{s}) + 2\text{H}_2(\text{g})$ B. $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{g}) + 2\text{H}_2(\text{g})$
C. $\text{CH}_4(\text{g}) \rightarrow \text{CH}_2(\text{g}) + \text{H}_2(\text{g})$ D. $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{s}) + 4\text{H}(\text{g})$
E. $\text{CH}_4(\text{g}) \rightarrow \text{CH}_3(\text{g}) + \text{H}(\text{g})$

12. Which statement is true of chemical reactions at equilibrium?

- A. The forward and reverse reactions proceed at equal rates
B. The forward and reverse reactions have stopped
C. The concentrations of the reactants and products are equal.
D. The forward and reverse reactions are both exothermic.
E. The forward and reverse reactions are both endothermic.

13. Solutions P, Q, R and S have the following properties:

P: $\text{pH} = 8$ Q: $[\text{H}_3\text{O}^+] = 1 \times 10^{-3} \text{ mol L}^{-1}$ R: $\text{pH} = 5$ S: $[\text{H}_3\text{O}^+] = 2 \times 10^{-7} \text{ mol L}^{-1}$

Which choice shows these in order of increasing acidity (least acidic first)?

- A. P,S,R,Q. B. S,P,R,Q C. S,R,P,Q. D. R,P,Q,S. E. Q,R,S,P.

14. At 50°C the ionic product of water (K_w) is 5.5×10^{-14} . What is the pH of a neutral aqueous solution at 50°C ?

- A. 1.0×10^{-7} B. 2.3×10^{-7} C. 6.63 D. 7.00 E. 13.26

15. A 0.1 mol L^{-1} aqueous solution of potassium ethanoate, $\text{KC}_2\text{H}_3\text{O}_2$, has a lower pH than a 0.1 mol L^{-1} solution of potassium cyanide, KCN. From this, you can correctly conclude that

- A. hydrocyanic acid, HCN, is a weaker acid than ethanoic acid, $\text{CH}_3\text{CO}_2\text{H}$
B. hydrocyanic acid, HCN, is less soluble in water than ethanoic acid, $\text{CH}_3\text{CO}_2\text{H}$
C. the cyanide ion, CN^- , is a weaker base than the ethanoate ion, CH_3CO_2^-
D. cyanides are less soluble in water than ethanoates.
E. ethanoate ion, CH_3CO_2^- partially dissociates to form hydronium ion, H_3O^+ .

16. When mixed at room temperature, which pair of 0.1 mol L^{-1} aqueous solutions of the solutes below will NOT give a precipitate?

- A. $\text{HCl} + \text{AgNO}_3$ B. $\text{NaOH} + \text{CuSO}_4$ C. $\text{CaCl}_2 + \text{Na}_2\text{CO}_3$
 D. $\text{H}_2\text{SO}_4 + \text{Ba}(\text{OH})_2$ E. $\text{NH}_4\text{NO}_3 + \text{K}_2\text{CrO}_4$

17. Which pair are members of a homologous series?

- A. C_2H_4 and C_2H_6 B. $\text{C}_2\text{H}_5\text{Cl}$ and $\text{C}_2\text{H}_4\text{Cl}_2$ C. CH_3OCH_3 and $\text{CH}_3\text{CH}_2\text{OH}$
 D. $\text{C}_3\text{H}_7\text{COOH}$ and $\text{C}_4\text{H}_9\text{COOH}$ E. $\text{C}_3\text{H}_5\text{COOH}$ and $\text{C}_3\text{H}_7\text{COOH}$

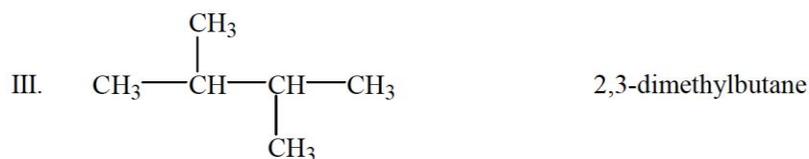
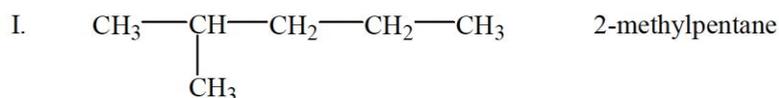
18. Which substance has the lowest boiling point?

- A. NH_3 B. H_2O C. HF D. CH_3OH E. CH_4

19. What are the oxidation states of chromium in $(\text{NH}_4)_2\text{Cr}_2\text{O}_7(\text{s})$ and $\text{Cr}_2\text{O}_3(\text{s})$?

	$(\text{NH}_4)_2\text{Cr}_2\text{O}_7(\text{s})$	$\text{Cr}_2\text{O}_3(\text{s})$
A	+2	+3
B	+6	+3
C	+7	+3
D	+6	+6
E	+7	+6

20. Which names are correct for the following isomers of C_6H_{14} ?

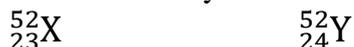


- A. I only B. II only C. III only
 D. I and II only E. I and III only

21. How many structural isomers that are not cyclic have the molecular formula C_5H_{10} ?
- A. 4 B. 5 C. 6 D. 7 E. 8

22. Which ion has the same electron configuration as Cl^- ?
- A. F^- B. P^+ C. Sc^{3+} D. Si^{4+} E. Mn^{2+}

23. The symbols of two atoms may be written as shown.



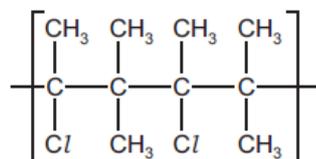
Which statement about these atoms is correct?

- A. They are different elements because they have different numbers of neutrons.
 B. They are different elements because they have different numbers of protons.
 C. They are allotropes of the same element.
 D. They are isotopes of the same element because they have the same mass number.
 E. They are isotopes of the same element because they have the same atomic number.
24. The electronegativities of four elements are given.

C	N	O	F
2.6	3.0	3.4	4.0

Which shows the bonds in the order of increasing polarity?

- A. $CO < OF < NO < CF$ B. $CF < CO < OF < NO$
 C. $NO < OF < CO < CF$ D. $C-F < NO < OF < CO$
 E. $OF < NO < CO < CF$
25. The structure below is a section of an addition polymer chain.



What is the name of the monomer that produced this polymer?

- A. 2-chloro-3-methylbutane B. 2-chloropentane
 C. 2-chloro-3-methylbut-2-ene D. 3-chloro-2-methylbut-2-ene
 E. 2-chloropent-2-ene

26. Which compound has the shortest CN bond?

- A. CH_3NH_2 B. CH_3CN C. CH_3CHNH
 D. $(\text{CH}_3)_2\text{CHNH}_2$ E. $(\text{CH}_3)_3\text{CNH}_2$

27. Which row or rows correctly shows a primary, a secondary and a tertiary alcohol?

	primary	secondary	tertiary
A	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_2 \\ \\ \text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CHOH} \\ \\ \text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CHOH} \\ \\ \text{CH}_2\text{OH} \end{array}$
B	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_3-\text{C}-\text{H} \\ \\ \text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{OH} \\ \\ \text{CH}_3 \end{array}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{H} \\ \\ \text{CH}_2\text{OH} \end{array}$
C	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_3-\text{C}-\text{H} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_3-\text{C}-\text{CH}_2\text{OH} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{CH}_2\text{OH} \\ \\ \text{CH}_3-\text{C}-\text{CH}_2\text{OH} \\ \\ \text{CH}_2\text{OH} \end{array}$
D	$\begin{array}{c} \text{H} \\ \\ \text{CH}_3-\text{C}-\text{OH} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{OH} \\ \\ \text{H} \end{array}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{OH} \\ \\ \text{CH}_3 \end{array}$

- A. Rows B and D B. Rows A and B C. Rows C and A
 D. Row D E. Row B

28. Which statement(s) are correct for metals?

- I. They conduct electricity because they have free moving ions
 II. They consist of a close-packed lattice of positive ions with delocalised electrons
 III. They are malleable because the metallic bonds are non-directional

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

29. A compound with molar mass $M = 102 \text{ g mol}^{-1}$ contains 58.8% carbon, 9.80% hydrogen and 31% oxygen by mass. What is its molecular formula?

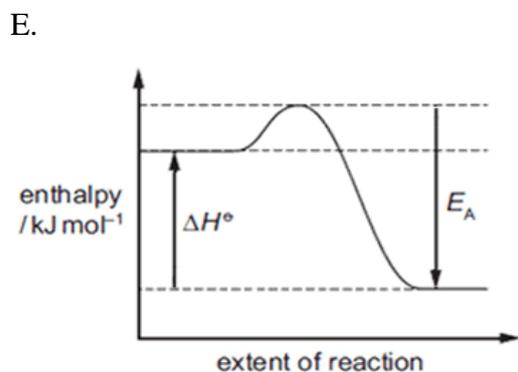
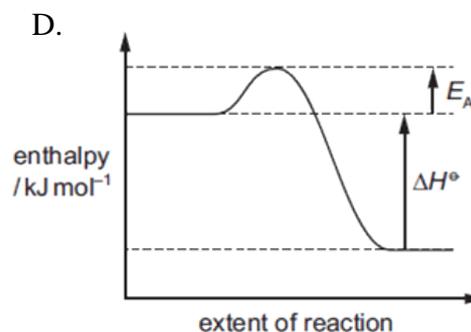
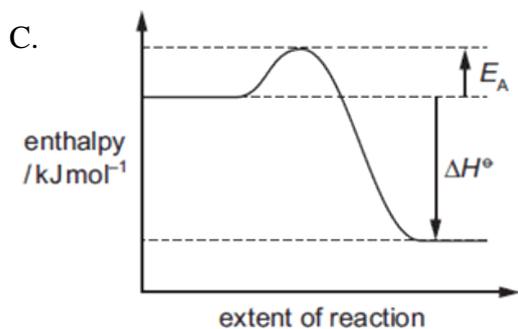
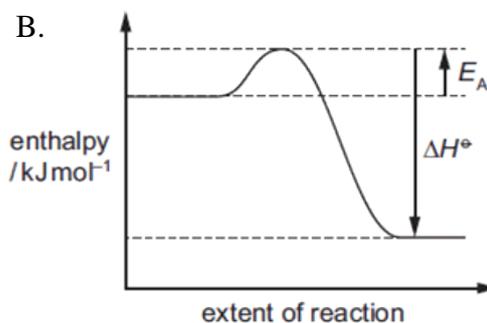
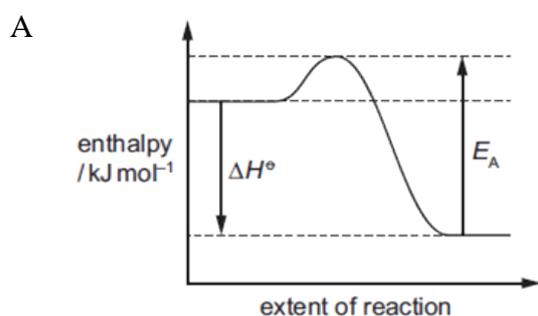
- A. $\text{C}_2\text{H}_{14}\text{O}_4$ B. $\text{C}_2\text{H}_5\text{O}$ C. $\text{C}_3\text{H}_4\text{O}_4$
 D. $\text{C}_5\text{H}_{10}\text{O}_2$ E. $\text{C}_6\text{H}_{14}\text{O}$

30. Nitric oxide, NO, and bromine vapour react together according to the following equation.

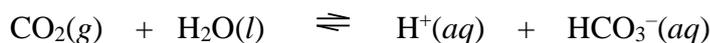


The reaction has an activation energy of $+5.4 \text{ kJ mol}^{-1}$.

What is the correct reaction pathway diagram for this reaction?



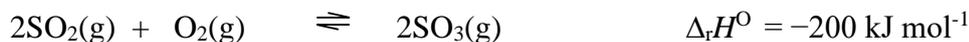
31. The overall pressure is increased on the mixture below which is at equilibrium. Which will be true of the mixture once equilibrium is restored?



- A. Higher product concentrations, and lower pH
B. Higher product concentrations and higher pH
C. Lower product concentrations and higher pH.
D. Lower product concentrations and lower pH.
E. There will be no change in product concentrations or pH.
32. $\text{H}_2 + \text{Cl}_2 \longrightarrow 2\text{HCl}$

Hydrogen and chlorine react according to the equation above. Which will be the result of reaction of 2.0 moles of H_2 and 1.5 moles of Cl_2 ?

- A. 3.5 mol of HCl
B. 4 mol HCl
C. 1.5 mol of HCl and 0.5 mol of H_2
D. 2.0 mol of HCl and 0.5 mol of Cl_2
E. 3.0 mol of HCl and 0.5 mol of H_2
33. Methylbuta-1,3-diene, $\text{CH}_2=\text{C}(\text{CH}_3)-\text{CH}=\text{CH}_2$ is a monomer in the manufacture of synthetic rubbers. Which compound would **NOT** produce this monomer on treatment with concentrated sulfuric acid at 170 °C?
- A. $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}(\text{OH})\text{CH}_3$
B. $\text{HOCH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{OH}$
C. $\text{HOCH}_2\text{CH}(\text{CH}_3)\text{CH}(\text{OH})\text{CH}_3$
D. $\text{HOCH}_2\text{C}(\text{CH}_3)(\text{OH})\text{CH}_2\text{CH}_3$
E. $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{CH}_3)\text{CH}_2\text{OH}$
34. The reaction below is part of the Contact process for production of sulfuric acid. The equilibrium constant K_c is 4.32 at 600 °C.



Which of the following statements is true if the temperature is decreased?

- A. K_c increases and more SO_3 is formed
B. K_c increases and less SO_3 is formed
C. K_c increases and there is no change in the amount of SO_3
D. K_c decreases and more SO_3 is formed
E. K_c decreases and less SO_3 is formed

35. For a titration of ammonia $\text{NH}_3(\text{aq})$ with $\text{HCl}(\text{aq})$, the ammonia must be diluted so that titration of 25.00 mL of the diluted NH_3 requires between 12.00 mL and 25.00 mL of HCl to reach equivalence. A rough titration showed that 1.0 mL of the undiluted NH_3 required 8.5 mL HCl to reach the equivalence point. Which dilution could be used to ensure the titre value is in the required range?
- A. 10.00 mL ammonia diluted to 250 mL B. 10.00 mL ammonia diluted to 500 mL
C. 25.00 mL ammonia diluted to 100 mL D. 25.00 mL ammonia diluted to 250 mL
E. 25.00 mL ammonia diluted to 500 mL

36. Hexane, $\text{C}_6\text{H}_{14}(\text{l})$, undergoes complete combustion according to the following equation.

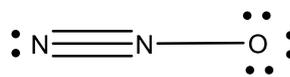
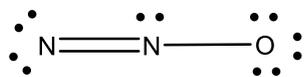
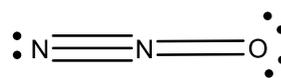
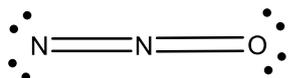
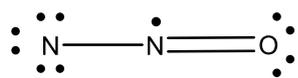


What mass of $\text{C}_6\text{H}_{14}(\text{l})$ must be reacted to produce 1000 kJ of energy?

$$M(\text{C}_6\text{H}_{14}) = 86.0 \text{ g mol}^{-1}$$

- A. 2.07 g B. 10.3 g C. 20.7 g D. 103 g E. 179 g
37. The following reaction is part of the Contact process for production of sulfuric acid.
- $$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g}) \quad K_c = 4.32 \text{ at } 600 \text{ }^\circ\text{C}$$
- If $[\text{O}_2(\text{g})]$ at equilibrium is 0.150 mol L^{-1} and $[\text{SO}_3(\text{g})]$ is 0.250 mol L^{-1} what is the concentration of $\text{SO}_2(\text{g})$?
- A. 0.0965 B. 0.310 C. 0.772 D. 0.878 E. 3.21
38. If 3-chloro-3-methylpentane is heated in alcoholic potassium hydroxide, how many structural (constitutional) alkene isomers could be produced?
- A. 0 B. 1 C. 2 D. 3 E. 4
39. Which of the following could be used to convert butan-1-ol to butan-1-amine?
- A. Treat with concentrated NH_3
B. Treat with concentrated H_2SO_4 then with concentrated NH_3
C. Treat with dilute H_2SO_4 then with concentrated NH_3
D. Treat with dilute H_2SO_4 followed by HCl and then with concentrated NH_3
E. Treat with SOCl_2 and then with concentrated NH_3

40. Which are the correct Lewis structures for N_2O ?



A. c and d

B. b and e

C. b, c and e

D. d and a

E. c and e