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# Chemistry

## Higher level

### Paper 1

2 November 2023

**Zone A** morning | **Zone B** morning | **Zone C** morning

1 hour

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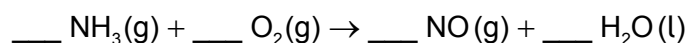
#### Instructions to candidates

- 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

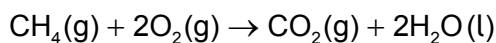
1	1 H 1.01	Atomic number Element Relative atomic mass												2 He 4.00						
2	3 Li 6.94	4 Be 9.01													5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31													13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 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)		
†			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. Ammonia reacts with oxygen to produce nitrogen (II) oxide and water.



What is the  $\text{NH}_3:\text{O}_2$  ratio in the balanced equation?

- A. 2:5
  - B. 4:5
  - C. 1:1
  - D. 2:1
2. Metal M reacts with 16.0 g of sulfur to produce 26.0 g of the compound  $\text{MS}_2$ . What is the relative atomic mass of M?
- A. 5
  - B. 10
  - C. 20
  - D. 40
3. 64 g of methane and 96 g of oxygen are reacted according to the equation.



What would be found in the reaction vessel at completion of the reaction?

- A.  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{l})$  only
  - B.  $\text{O}_2(\text{g})$ ,  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{l})$  only
  - C.  $\text{CH}_4(\text{g})$ ,  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{l})$  only
  - D.  $\text{CH}_4(\text{g})$ ,  $\text{O}_2(\text{g})$ ,  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{l})$
4. Gallium ( $A_r = 69.72$ ) consists of two stable isotopes, Ga-69 and Ga-71. What is the relative abundance of Ga-71?
- A. 36 %
  - B. 40 %
  - C. 60 %
  - D. 64 %

5. The first three ionization energies for two elements, X and Y, are:

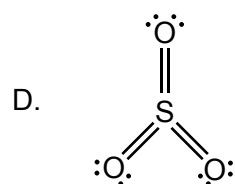
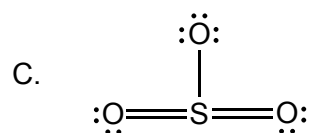
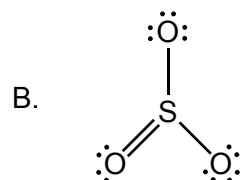
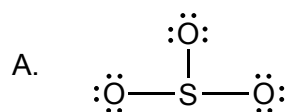
	Ionization energies ( $\text{kJ mol}^{-1}$ )		
	First	Second	Third
X	900	1757	14 849
Y	1086	2350	4620

Which pair of elements represent X and Y, respectively?

- A. Lithium and beryllium
- B. Lithium and carbon
- C. Beryllium and carbon
- D. Helium and beryllium
6. Which **one** of the following observations provides evidence that matter is composed of atoms?
- A. The line emission spectra of hydrogen produce four visible lines.
- B. Sodium chloride is soluble in water and conducts electricity in the aqueous state.
- C. Water is a liquid at room temperature, but hydrogen sulfide and hydrogen selenide are gases.
- D. 12.0 g of carbon combines with either 16.0 g or 32.0 g of oxygen but never any other ratio.
7. Which group of elements have the most similar atomic radii?
- A. Li, Be, B, C
- B. Fe, Co, Ni, Cu
- C. K, Ca, Br, Kr
- D. Ne, Ar, Kr, Xe

8. Which aqueous solutions would have a different wavelength of maximum absorbance from  $0.10 \text{ mol dm}^{-3} \text{ FeSO}_4$ ?
- I.  $0.01 \text{ mol dm}^{-3} \text{ FeSO}_4$
  - II.  $0.10 \text{ mol dm}^{-3} \text{ Fe}_2(\text{SO}_4)_3$
  - III.  $0.10 \text{ mol dm}^{-3} \text{ FeSCN}^{2+}$
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III
9. For which molecule can resonance structures be used to describe the bonding?
- A. HCN
  - B.  $\text{H}_2\text{CO}_3$
  - C.  $\text{PCl}_3$
  - D.  $\text{SO}_2$
10. Which substance has high volatility in its pure state **and** high electrical conductivity in aqueous solutions?
- A.  $\text{C}_6\text{H}_5\text{Cl}$
  - B. HCl
  - C. NaCl
  - D. HCN
11. Which substance exhibits only London (dispersion) forces between molecules?
- A.  $\text{PF}_5$
  - B.  $\text{SF}_4$
  - C.  $\text{SO}_2$
  - D.  $\text{XeO}_2$

12. Which is the correct structure of  $\text{SO}_3$ , based on the lowest formal charge?



13. What bond angle is most likely found with an  $\text{sp}^2$  hybridized carbon as the central atom?

- A.  $90^\circ$
- B.  $109.5^\circ$
- C.  $120^\circ$
- D.  $180^\circ$

14. Which reactions release heat?

- I.  $\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$
- II.  $\text{Na}^+\text{(g)} + \text{e}^- \rightarrow \text{Na(g)}$
- III.  $\text{NH}_3\text{(g)} \rightarrow \text{NH}_3\text{(l)}$

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

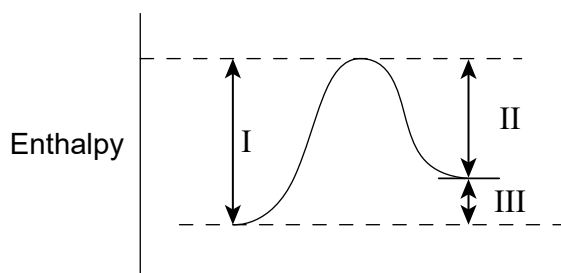
15. Which expression represents the calculation used to obtain the  $\Delta H^\ominus$  value for the conversion of oxygen to one mole of ozone ( $\text{O}_3$ )?

		$\Delta H^\ominus, \text{kJ}$
Eqn (i)	$2\text{CO}_2 \rightarrow 2\text{CO} + \text{O}_2$	+566
Eqn (ii)	$3\text{CO} + \text{O}_3 \rightarrow 3\text{CO}_2$	–992

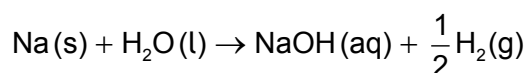
- A.  $-566 - 992$
- B.  $-566 + 992$
- C.  $1.5 \times (-566) + 992$
- D.  $1.5 \times (-566) - 992$



16. Which expression represents the calculation of  $\Delta H$ ?



- A. I–II  
 B. II–I  
 C. I–III  
 D. II–III
17. Which steps of this reaction have positive enthalpy changes?



- I. Atomization  
 II. Ionization  
 III. Hydration
- A. I and II only  
 B. I and III only  
 C. II and III only  
 D. I, II and III
18. Which combination of values of  $\Delta H$  and  $\Delta S$  belongs to a reaction which is spontaneous at low temperatures but not spontaneous at high temperatures?

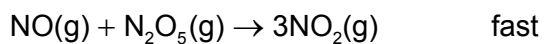
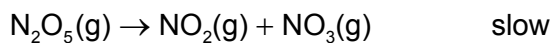
	$\Delta H$	$\Delta S$
A.	Negative	Negative
B.	Negative	Positive
C.	Positive	Positive
D.	Positive	Negative

19. Which statement describes a role that a catalyst might have in increasing the rate of reaction by providing an alternative mechanism?
- A. It increases frequency of collisions between molecules
  - B. It increases energy of collisions between molecules
  - C. It increases proportion of molecules colliding in correct orientation
  - D. It increases proportion of molecules with a given energy
20. The rate of the reaction  $2\text{N}_2\text{O}_5(\text{g}) \rightarrow 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g})$  can be expressed as rate of change of concentration of oxygen with respect to time,  $\Delta[\text{O}_2]/\Delta t$ .

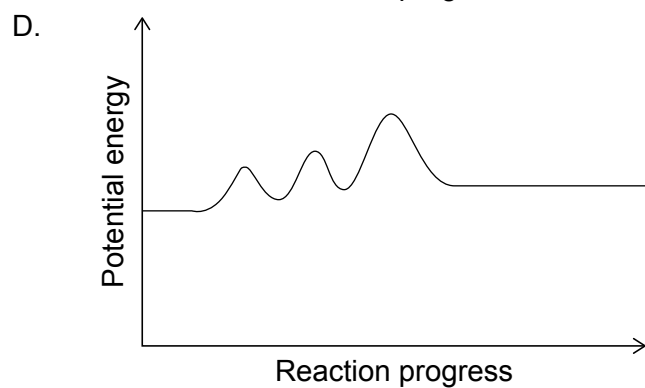
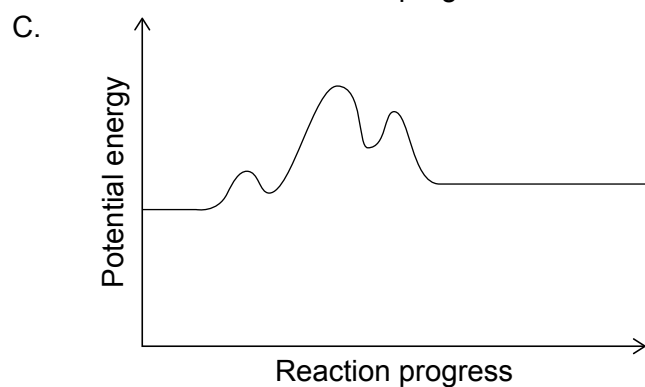
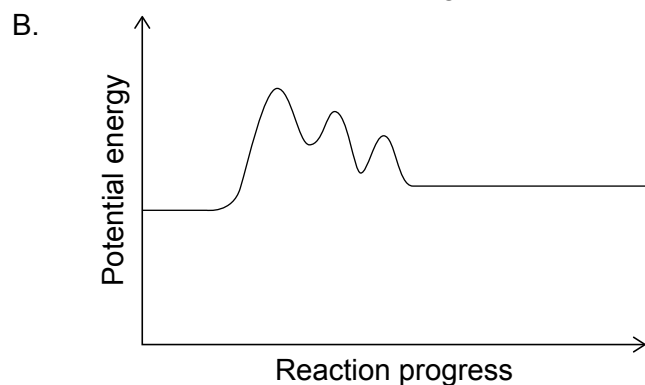
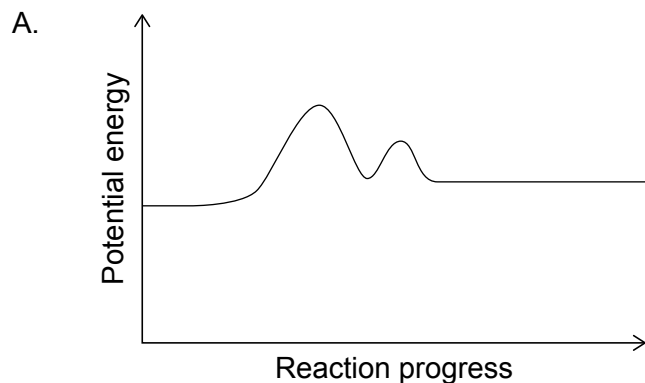
Which expression would give the same numerical value for the rate?

- A.  $-\frac{1}{2} \times \Delta[\text{N}_2\text{O}_5] / \Delta t$
- B.  $-2 \times \Delta[\text{N}_2\text{O}_5] / \Delta t$
- C.  $-\frac{1}{4} \times \Delta[\text{NO}_2] / \Delta t$
- D.  $4 \times \Delta[\text{NO}_2] / \Delta t$

21. A proposed mechanism for the decomposition of  $\text{N}_2\text{O}_5$  is



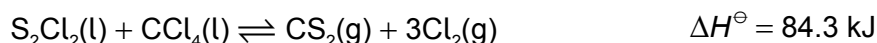
Which potential energy profile illustrates this proposed mechanism?



22. Which factor is dependent on temperature?

- A. Activation energy,  $E_a$
- B. Pre-exponential factor,  $A$
- C. Rate constant,  $k$
- D. Gas constant,  $R$

23. What can increase the amount of  $\text{CS}_2(\text{g})$  present in the following system already at equilibrium?



- A. Adding a catalyst to the system
- B. Increasing the volume of the reaction vessel
- C. Adding some  $\text{Cl}_2(\text{g})$  to the system
- D. Cooling the system

24. The system  $2\text{A}(\text{g}) \rightleftharpoons \text{B}(\text{g}) + 3\text{C}(\text{g})$  is at equilibrium where the concentrations of A, B and C are all  $2 \text{ mol dm}^{-3}$ .

What is the value of the equilibrium constant,  $K_c$ ?

- A. 2
- B. 3
- C. 4
- D. 8

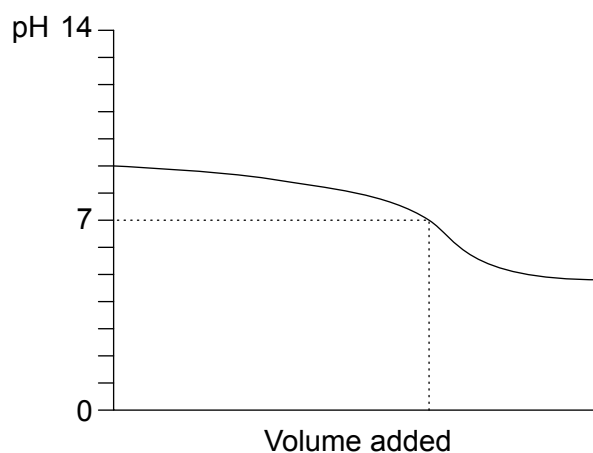
25. Sulfur dioxide emissions from coal-fired power plants is a source of acid deposition. Which are pre-combustion methods of reducing sulfur dioxide emissions?

- I. Wash flue gases with crushed limestone and water.
  - II. Crush and wash the coal.
  - III. Crush and mix coal with a sulfur solvent, then wash.
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

26. Which combination will make a buffer solution when  $100\text{ cm}^3$  of each is mixed?

- A.  $0.1\text{ mol dm}^{-3}$  NaCl and  $0.1\text{ mol dm}^{-3}$  HCl
- B.  $0.2\text{ mol dm}^{-3}$  NaCl and  $0.1\text{ mol dm}^{-3}$  HCl
- C.  $0.1\text{ mol dm}^{-3}$   $\text{NH}_3$  and  $0.1\text{ mol dm}^{-3}$  HCl
- D.  $0.2\text{ mol dm}^{-3}$   $\text{NH}_3$  and  $0.1\text{ mol dm}^{-3}$  HCl

27. What type of titration is represented by the titration curve shown?



- A. Weak acid added to a weak base
- B. Weak base added to a weak acid
- C. Strong base added to a weak acid
- D. Strong acid added to a weak base

28. What is the pH of a  $0.1\text{ mol dm}^{-3}$  weak acid with  $K_a = 1 \times 10^{-5}$ ?

- A. 2
- B. 3
- C. 4
- D. 5

29. The acid  $\text{H}_2\text{S}$  reacts with an active metal, M. Which combination shows the correct role of  $\text{H}_2\text{S}$ , and product formed from the reaction?

	Role of $\text{H}_2\text{S}$	Product from $\text{H}_2\text{S}$ reaction
A.	Oxidizing agent	$\text{H}_2(\text{g})$
B.	Oxidizing agent	$\text{S}(\text{s})$
C.	Reducing agent	$\text{H}_2(\text{g})$
D.	Reducing agent	$\text{S}(\text{s})$

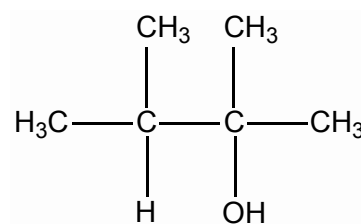
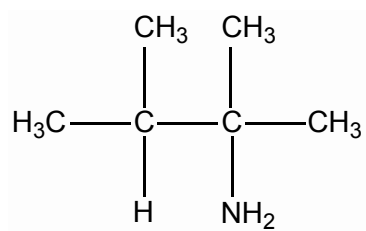
30. What is formed at the cathode in the electrolysis of  $2.0 \text{ mol dm}^{-3}$  sodium chloride solution?

- A.  $\text{Cl}_2(\text{g})$
- B.  $\text{H}_2(\text{g})$
- C.  $\text{Na}(\text{l})$
- D.  $\text{O}_2(\text{g})$

31. Which combination of atomic mass and charge on ion will result in the largest mass of a metal M being electroplated by a fixed current for a fixed time?

	Atomic mass	Charge on ion
A.	Large	High
B.	Large	Low
C.	Small	High
D.	Small	Low

32. What is the correct classification for the two compounds given?



	Type of amine	Type of alcohol
A.	Primary	Primary
B.	Tertiary	Tertiary
C.	Tertiary	Primary
D.	Primary	Tertiary

33. Which is the first product of distillation from the reaction of propan-1-ol with acidified potassium dichromate (VI)?

- A.  $\text{CH}_3\text{COCH}_3$
- B.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- C.  $\text{CH}_3\text{CH}_2\text{CHO}$
- D.  $\text{CH}_3\text{CH}_2\text{COOH}$

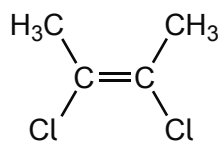
34. Which compounds react with HBr to produce 2-bromobutane?

- I.  $\text{CH}_2=\text{CH}-\text{CH}_2-\text{CH}_3$
  - II.  $\text{CH}_3-\text{CH}=\text{CH}-\text{CH}_3$
  - III.  $\text{H}-\text{C}\equiv\text{C}-\text{CH}_2-\text{CH}_3$
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

35. Which compound is likely to have the highest  $S_N1$  rate of reaction with  $\text{OH}^-$  ions?

- A.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$  in ethanol solvent
- B.  $(\text{CH}_3)_3\text{CBr}$  in ethanol solvent
- C.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$  in pentane solvent
- D.  $(\text{CH}_3)_3\text{CBr}$  in pentane solvent

36. What are the preferred IUPAC classifications of this structure of 2,3-dichlorobut-2-ene?



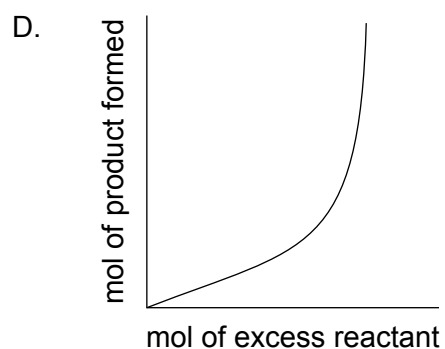
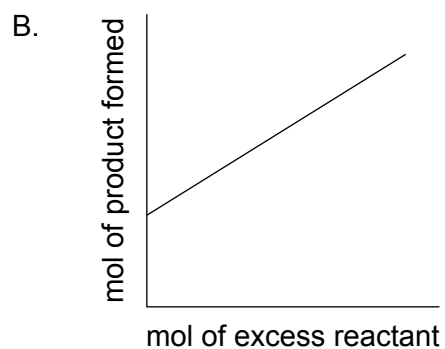
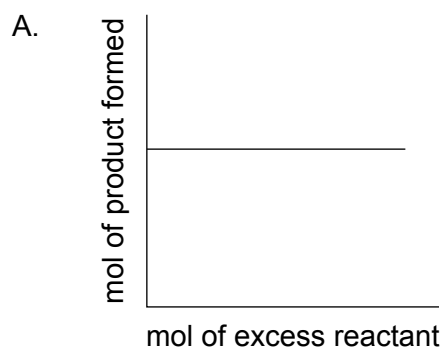
	<b>Cis-trans</b>	<b>E/Z</b>
A.	Cis	(E)
B.	Cis	(Z)
C.	Trans	(E)
D.	Trans	(Z)

37. Which procedure is most likely to produce a systematic error in determining the original concentration of  $\text{NaOH(aq)}$  by titration with  $\text{HCl(aq)}$ ?

- A. Repeating the titration only once instead of five times
- B. Using various burettes for each trial instead of the same one
- C. Using a varying number of drops of the indicator for the titrations
- D. Titrating the sample two days after preparing it instead of on the day it was prepared



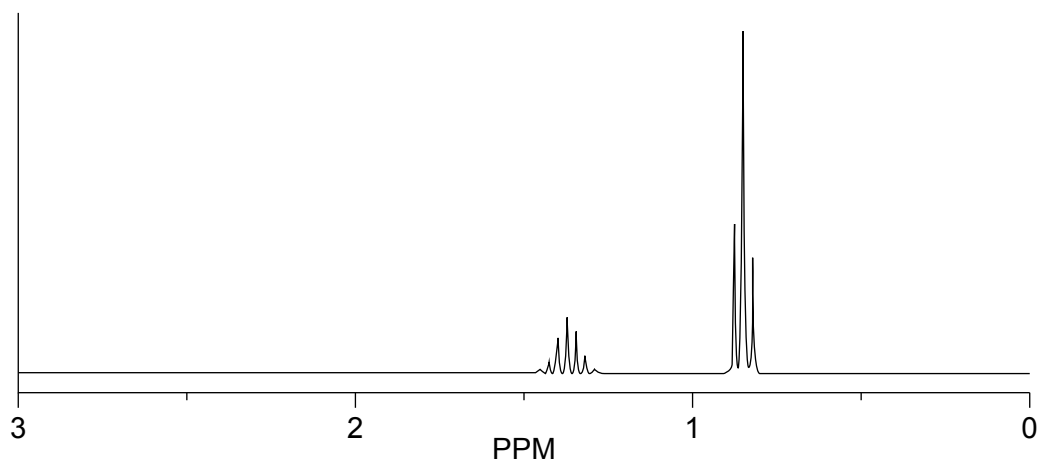
38. Which graph shows the relationship between quantity of product formed and quantity of excess reactant after the limiting reactant is consumed?



39. Which instrument can be used to distinguish between enantiomers?

- A. IR spectrometer
- B. Mass spectrometer
- C. Polarimeter
- D. NMR spectrometer

40. Which compound has this high resolution  $^1\text{H}$  NMR spectrum?



- A. Propane
  - B. Propanal
  - C. Propanone
  - D. Propanoic acid
-

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**References:**

40. The University of Sydney, n.d. [*Interactive NMR spectrum.*] [online] Available at: <https://scilearn.sydney.edu.au/OrganicSpectroscopy/NMRSpectraExamples.cfm?ID=25&unit=#> [Accessed 13 June 2022].

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