



CHEMISTRY

Higher Level

Answer Key

Thursday 6 May 1999 (afternoon)

Grade 1 2 3 4 5 6 7
Paper 1 Boundaries: Mark 0-9 10-15 16-21 22-25 26-28 29-32 >33 1 hour
out of 40

This examination paper consists of 40 questions.

Each question offers 4 suggested answers.

The maximum mark for this paper is 40.

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.

Calculators are NOT permitted for this examination paper.

Performance
per
Topic

Topic	Teaching Hours	Questions	Mean % Correct
Stoichiometry	10	1,2,3,4	73.9
Atomic Theory	9	5,6,7	74.1
Periodicity	10	8,9,10	51.5
Bonding	16	11,12,13,14	62.8
States of Matter	5	15,16,17	69.3
Energetics	14	18,19,20	64.5
Kinetics	11	22,23,24	75.1
Equilibrium	10	25,26,27	71.3
Acids and Bases	14	28,29,31	57.0
Oxidation/Reduction	13	32,33,34	66.7
Organic Chemistry	22	35,36,37,38,39,40	56.6

EXAMINATION MATERIALS

Required:

Optically Mark Read (OMR) answer sheet

Allowed:

May 1999 HL

SUBJECT: 420
QUESTION

INTERNATIONAL BACCALAUREATE
MULTIPLE CHOICE ANALYSIS - QUESTION NUMBER ORDER
20 % OF TOTAL MARK
10:52:25
38 QUESTIONS 4 CHOICES
DISCRIMINATION INDEX

	A	B	C	D	BLANK	HL	DIFFICULTY INDEX	
1	128	(2251)✓	528	(175)✓	2		73.03	.22
2	52	54	34	413	1		95.39	.10
3	478	(1903)✓	286	655	1		61.77	.50
4	(2012)✓	271	130	257	13		65.28	.51
5	(2499)✓	248	76	171	2		81.08	.35
6	580	(2149)✓	182	287	3		69.72	.39
7	376	208	(2208)✓	487			71.64	.41
8	576	(1914)✓	105	99	3		62.10	.46
9	(618)✓	1678	679	(2226)✓	8		(20.03)	.46
10	68	66	721	385	1		72.22	.03
11	(2268)✓	264	226	324	1		73.58	.31
12	988	(1609)✓	297	162	3		45.71	.36
13	216	247	(2450)✓	759	6		79.49	.45
14	479	(1608)✓	235	162	1		52.17	.58
15	65	60	117	(2810)✓	1		92.11	.17
16	131	1015	708	(1221)✓	7		(59.61)	.36
17	177	230	316	(2351)✓	8		76.28	.37
18	291	317	(1971)✓	496	7		63.95	.42
19	179	(2432)✓	238	225	8		78.90	.37
20	1165	251	100	(1564)✓	2		50.74	.00
21	1960	365	372	560	4		89.26	.26
22	303	282	393	(2119)✓	6		67.16	.54
23	138	47	145	(2751)✓	1		54.21	.47
24	400	92	(2070)✓	518	1		92.37	.14
25	(1671)✓	241	655	625	10		61.67	.40
26	172	187	(2073)✓	505	5		75.79	.40
27	65	58	110	(2847)✓	8		68.75	.41
28	84	(1902)✓	392	601	6		89.26	.26
29	562	449	207	(2336)✓	6		67.16	.54
30	638	1507	834	163	16		54.21	.47
31	492	(1022)✓	583	825	14		92.37	.14
32	207	228	(2108)✓	237	16		68.39	.35
33	214	(2013)✓	591	289	12		65.96	.42
34	606	(2027)✓	299	610	12		65.76	.37
35	190	511	(1691)✓	255	19		59.44	.61
36	409	415	618	(1832)✓	27		73.03	.44
37	(572)✓	171	(2251)✓	222	29		51.00	.55
38	(1068)✓	594	622	273	21		34.65	.53
39	256	716	1052	317	32		67.09	.52
40	(2068)✓		397		44			

NUMBER OF CANDIDATES = 3062

Handwritten mark

1. Which sample has the greatest mass?

- A. 1.0 mol of N_2H_4 $\overset{Mr}{38.0} \Rightarrow 38.0\text{ g}$
- (B) 2.0 mol of N_2 $28.0 \Rightarrow 56.0\text{ g}$
- C. 3.0 mol of NH_3 $17.0 \Rightarrow 51.0\text{ g}$
- D. 25.0 mol of H_2 $2.0 \Rightarrow 50.0\text{ g}$

2. A compound contains 24 % magnesium, 28 % silicon and 48 % oxygen by mass. What is its empirical formula?

- A. $MgSiO$
- B. Mg_2SiO
- C. $MgSi_2O$
- (D) $MgSiO_3$

\underline{Mg}	\underline{Si}	\underline{O}
$\frac{24}{24}$	$\frac{28}{28}$	$\frac{48}{16}$
1	1	3

3. What is the mass in grams of one molecule of propanol, C_3H_7OH ?

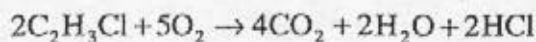
(Avogadro's constant $6.0 \times 10^{23} \text{ mol}^{-1}$)

$$36 + 8 + 16 = 60$$

6.0×10^{23} molecules weigh 60 g
 1 molecule weighs $\frac{60 \text{ g/mol}}{6.0 \times 10^{23} \text{ molecules/mol}} \times 1 \text{ molecule}$
 $= 10 \times 10^{-23} \text{ g}$
 $= 1.0 \times 10^{-22} \text{ g}$

- A. 60
- (B) 1.0×10^{-22}
- C. 1.0×10^{-23}
- D. 3.6×10^{25}

4. Chloroethene, C_2H_3Cl , reacts with oxygen according to the equation below:



How many moles of CO_2 are produced when 3.0 mol of C_2H_3Cl and 3.0 mol of O_2 are reacted?

(A) 2.4 ✓

B. 3.0

C. 4.0

D. 6.0

2.0 mol C_2H_3Cl react with 5.0 mol O_2
 3.0 " " " " 7.5 mol O_2

$\therefore n_{O_2}$ is limiting

5.0 mol $O_2 \rightarrow 4.0$ mol CO_2

$\therefore 3.0$ " $O_2 \rightarrow \frac{4.0}{5.0} \times 3.0 = 2.4$ mol CO_2

or $\frac{1}{4} n_{CO_2} = \frac{1}{5} n_{O_2} \therefore n_{CO_2} = \frac{4}{5} \times 3.0$

5. All isotopes of tin have the same

I. number of protons; ✓

II. number of neutrons; ✗

III. mass number. ✗

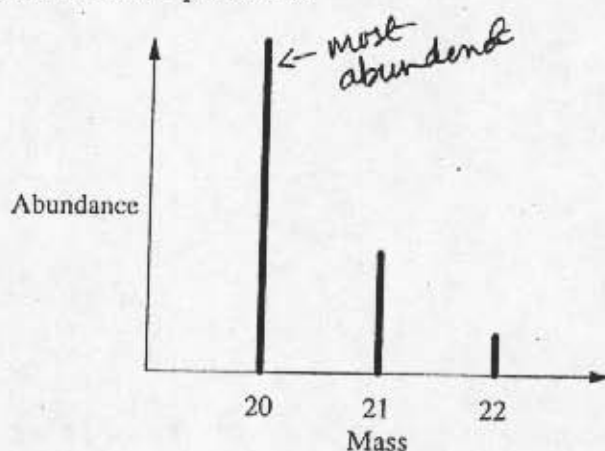
(A) I only

B. II only

C. III only

D. I and III only

The following diagram should be used to answer question 6.



6. According to the mass spectrum above, the relative atomic mass of the element shown is best expressed as
- A. 20.0. ✗
 - B. between 20.0 and 21.0. ✓**
 - C. 21.0. ✗
 - D. between 21.0 and 22.0. ✗
7. Using the Aufbau Principle, deduce which element below has the greatest number of unpaired electrons in its ground state.
- A. $Z=13$
 - B. $Z=14$
 - C. $Z=15$ ✓**
 - D. $Z=16$

$1s^2 2s^2 2p^6$ $3s^2 3p^1$
 $\underbrace{\hspace{1.5cm}}_{10}$
 $3s^2 3p^2$
 $3s^2 3p^3$ $\uparrow \uparrow \uparrow$
 $3s^2 3p^4$
8. Which element has the lowest first ionization energy?
- A. Li
 - B. Na ✓**
 - C. Mg
 - D. Al

IE

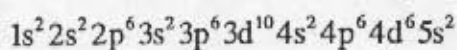
→ increases

↓ decreases

9. Based on melting points, the dividing line between ionic and covalent chlorides of the elements Mg to S lies between

- (A) Mg and Al. ✓
- B. Al and Si.
- C. Si and P. ✗
- D. P and S. ✗

10. In which region of the Periodic Table would the element with the electronic structure below be located?

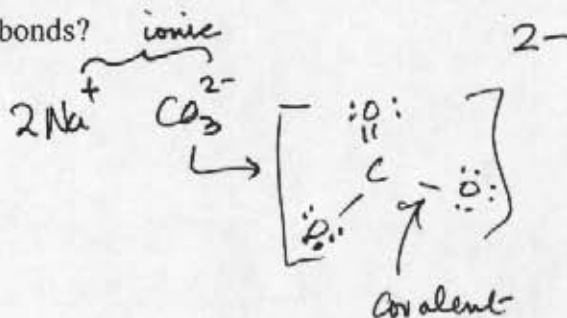


↑ partially filled d-orbital

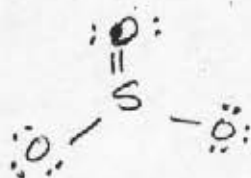
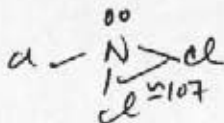
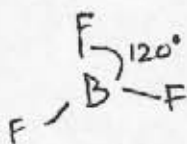
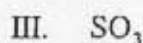
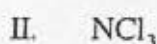
- A. group 6
- B. noble gases
- C. s block
- (D) d block ✓

11. Which compound contains both covalent and ionic bonds?

- (A) sodium carbonate, Na_2CO_3 ✓
- B. magnesium bromide, MgBr_2
- C. dichloromethane, CH_2Cl_2
- D. ethanoic acid, CH_3COOH



12. In which of the following gaseous molecules are the bond angles equal to 120° ?



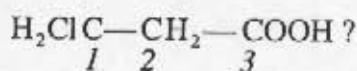
A. I only

☒ B. I and III only ✓

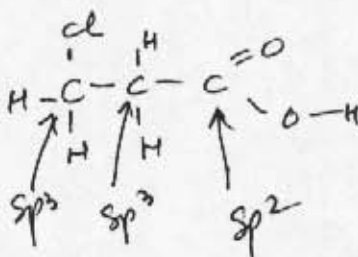
C. II and III only

D. I, II and III

13. What are the types of hybridization of the carbon atoms in the compound



- | | <u>I</u> | <u>2</u> | <u>3</u> |
|-------------------------------------|-----------------|-----------------|-----------------|
| A. | sp^2 ✗ | sp^2 ✗ | sp^2 |
| B. | sp^3 | sp^2 ✗ | sp ✗ |
| <input checked="" type="radio"/> C. | sp^3 | sp^3 | sp^2 ✓ |
| D. | sp^3 | sp^3 | sp ✗ |



14. In which of the following pairs does the second substance have the lower boiling point?

A. F_2, Cl_2 → large mass / dispersion forces

☒ B. $\text{H}_2\text{O}, \text{H}_2\text{S}$ ← H-bonding in H_2O , no H-bonding in H_2S ✓

C. $\text{C}_2\text{H}_6, \text{C}_3\text{H}_8$ → large mass / dispersion forces

D. $\text{CH}_3\text{OCH}_3, \text{CH}_3\text{CH}_2\text{OH}$ H-bonding

15. All of the following are characteristic properties of gases EXCEPT

- A. they can expand without limit. ✓
- B. they diffuse readily. ✓
- C. they are easily compressed. ✓
- (D) they have high densities. ✗ *low densities*

16. A 250 cm³ sample of an unknown gas has a mass of 1.42 g at 35°C and 0.85 atmospheres. Which expression gives its molar mass, M_r ? ($R = 82.05 \text{ cm}^3 \text{ atm K}^{-1} \text{ mol}^{-1}$) $\rightarrow 35 + 273 = 308 \text{ K}$

- A. $\frac{1.42 \times 82.05 \times 35}{0.25 \times 0.85}$ ✗
- B. $\frac{1.42 \times 82.05 \times 308}{\cancel{0.25} \times 0.85}$
- C. $\frac{1.42 \times 250 \times 0.85}{82.05 \times 308}$
- (D) $\frac{1.42 \times 82.05 \times 308}{250 \times 0.85}$ ✓

$$PV = nRT$$

$$= \frac{m}{M} RT$$

$$\therefore M = \frac{m}{V} \frac{RT}{P}$$

$$= \frac{1.42 \text{ g}}{250 \text{ cm}^3} \times 82.05 \frac{\text{cm}^3 \text{ atm}}{\text{K mol}} \times \frac{308 \text{ K}}{0.85 \text{ atm}}$$

17. A mixture of 0.40 mol of N₂, 0.20 mol of O₂ and 0.20 mol of CO₂ has a total pressure of 1.6 atmospheres. What is the partial pressure of O₂ in atmospheres?

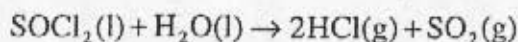
- A. 0.20
- B. 0.25
- C. 0.32
- (D) 0.40 ✓

$$P_{O_2} = X_{O_2} \times P_{\text{tot}} \quad \leftarrow \text{mol fraction}$$

$$= \frac{0.20}{(0.40 + 0.20 + 0.20)} \times 1.6$$

$$= \frac{0.20}{0.80} \times 1.6 = 0.40$$

18. Excess thionyl chloride, SOCl_2 , can be removed from a reaction mixture by reacting it with water according to the equation;



Use the following data to calculate ΔH^\ominus for this reaction.

	$\text{SOCl}_2(\text{l})$	$\text{H}_2\text{O}(\text{l})$	$\text{HCl}(\text{g})$	$\text{SO}_2(\text{g})$
ΔH_f^\ominus (kJ mol ⁻¹)	-245.6	-285.8	-92.3	-296.8

A. -142.3

B. -50.0

(C) +50.0 ✓

D. +142.3

$$\begin{aligned}\Delta H_{\text{rxn}}^\ominus &= \sum \Delta H_{\text{f,p}}^\ominus - \sum \Delta H_{\text{f,r}}^\ominus \\ &= [2(-92.3) + (-296.8)] - [(-245.6) + (-285.8)] \\ &= -481.4 - (-531.4) \\ &= -481.4 + 531.4 = +50.0\end{aligned}$$

19. 200 J of energy were given to a 10 g sample of copper. If the temperature of the copper increased by 50°C, what is the specific heat capacity of the copper?

A. 0.25 J g⁻¹ °C⁻¹

(B) 0.40 J g⁻¹ °C⁻¹ ✓

C. 2.5 J g⁻¹ °C⁻¹

D. 4.0 J g⁻¹ °C⁻¹

$$\begin{aligned}Q &= mc\Delta T \\ 200\text{ J} &= 10\text{ g} \times c \times 50^\circ\text{C} \\ \therefore c &= \frac{200\text{ J}}{500\text{ g}^\circ\text{C}} \\ &= 0.40\text{ J g}^{-1}\text{ }^\circ\text{C}^{-1}\end{aligned}$$

20. Which of the changes below occurs with the greatest increase in entropy?

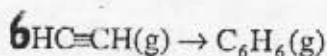
A. $\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{Na}^+(\text{aq}) + 2\text{OH}^-(\text{aq})$ (s) + (l) → (aq) + (aq)

B. $\text{NH}_3(\text{g}) + \text{HCl}(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{s})$ 2(g) → (s) ✗

C. $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightarrow 2\text{HI}(\text{g})$ 2(g) → 2(g) ✗

(D) $\text{C}(\text{s}) + \text{CO}_2(\text{g}) \rightarrow 2\text{CO}(\text{g})$ ✓
 1 (g) 2 (g)

21. For the reaction;



$\Delta H^\ominus = -597.3 \text{ kJ}$ and $\Delta S^\ominus = -0.33 \text{ kJ K}^{-1}$. This reaction

$$\Delta G = \Delta H - T\Delta S$$

As T increases, rxn becomes less spontaneous

(A) is spontaneous at 300K and becomes non-spontaneous at higher temperatures. ✓

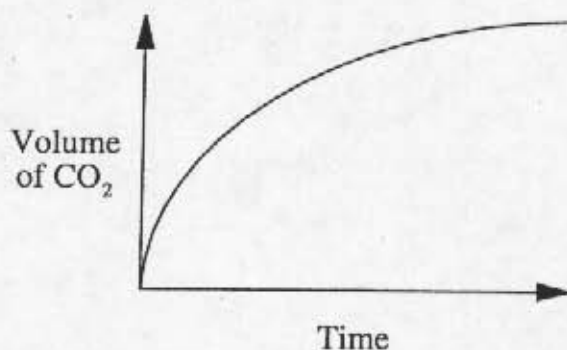
B. is spontaneous at 300K and becomes non-spontaneous at lower temperatures. ✗

C. is non-spontaneous at 300K and becomes spontaneous at higher temperatures. ✗

D. is non-spontaneous at 300K and becomes spontaneous at lower temperatures. ✗

$$\begin{aligned}\Delta G &= \Delta H - T\Delta S \\ &= -597.3 - 300(-0.33) \\ &= -597.3 + 99 \\ &= -498.3 \text{ kJ}\end{aligned}$$

22. The reaction between excess calcium carbonate and hydrochloric acid can be followed by measuring the volume of carbon dioxide produced with time. The results of one such reaction are shown below.



How does the rate of this reaction change with time and what is the main reason for this change?

A. The rate increases with time because the calcium carbonate particles get smaller. ✗

B. The rate increases with time because the acid becomes more dilute. ✗

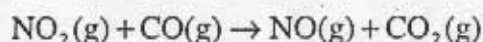
C. The rate decreases with time because the calcium carbonate particles get smaller.

(D) The rate decreases with time because the acid becomes more dilute. ✓

23. Most reactions occur in a series of steps, one of which is the rate determining step. The rate determining step is so called because it is the

- A. first step. ∇
- B. last step. \times
- C. fastest step. \times
- ☒ D. slowest step. \checkmark

24. The reaction between nitrogen dioxide and carbon monoxide is given by the equation below;



According to the following experimental data, what is the rate equation?

[NO₂] / mol dm⁻³ [CO] / mol dm⁻³ Rate / mol dm⁻³ s⁻¹

0.10	$\times 3$ constant
0.30	
0.30	

0.10	constant $\times 3$
0.10	
0.30	

1.0×10^{-6} $\therefore \propto [\text{NO}_2]^2$
 9.0×10^{-6} \downarrow same $\therefore \propto [\text{CO}]^0$
 9.0×10^{-6}

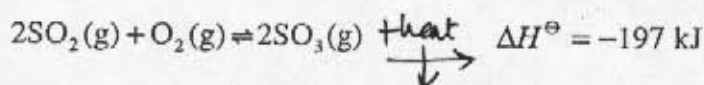
$\therefore \text{rate} = k [\text{NO}_2]^2$

- A. Rate = $k[\text{NO}_2][\text{CO}]^{\times}$
- B. Rate = $k[\text{CO}]^2 \times$
- ☒ C. Rate = $k[\text{NO}_2]^2 \checkmark$
- D. Rate = $k[\text{NO}_2]^3 \times$

25. For a reaction which goes to completion, the equilibrium constant, K_c , is

- ☒ A. $\gg 1 \checkmark$
- B. $\ll 1$
- C. $= 1$
- D. $= 0$

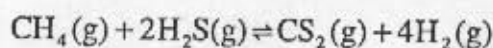
26. The reaction between sulfur dioxide and oxygen occurs according to the equation below;



A higher equilibrium concentration of SO_3 will be produced by all of the following changes in reaction conditions EXCEPT

- A. increasing the pressure. ✓ *high P \Rightarrow low vol \Rightarrow products occupying less vol. favoured*
 B. adding more O_2 . ✓
 C. adding a catalyst. ✗
 D. decreasing the temperature. ✓

27. The reaction between methane and hydrogen sulfide is represented by the equation below;



What is the equilibrium expression for this reaction?

- A. $\frac{[\text{CS}_2][\text{H}_2]}{[\text{CH}_4][\text{H}_2\text{S}]}$ ✗
 B. $\frac{4[\text{CS}_2][\text{H}_2]}{2[\text{CH}_4][\text{H}_2\text{S}]}$ ✗
 C. $\frac{[\text{CS}_2] + 4[\text{H}_2]}{[\text{CH}_4] + 2[\text{H}_2\text{S}]}$ ✗
 D. $\frac{[\text{CS}_2][\text{H}_2]^4}{[\text{CH}_4][\text{H}_2\text{S}]^2}$ ✓

$$K_c = \frac{[\text{CS}_2][\text{H}_2]^4}{[\text{CH}_4][\text{H}_2\text{S}]^2}$$

28. Which of the following 1 mol dm^{-3} solutions will be the poorest conductor of electricity?

- A. hydrochloric acid *strong acid \Rightarrow strong electrolyte*
 B. ethanoic acid *weak acid \Rightarrow weak electrolyte*
 C. sodium hydroxide *strong base \Rightarrow strong electrolyte*
 D. ammonium chloride *salt \Rightarrow " "*

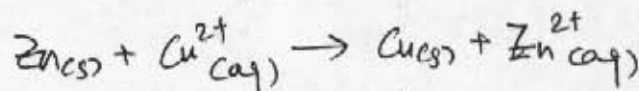
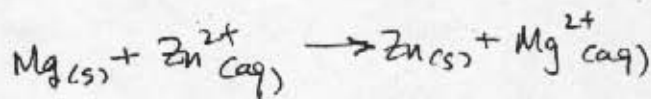
32. Zinc metal can supply electrons to copper ions and magnesium metal can supply electrons to zinc ions. Which is the strongest reducing agent?

A. copper ions ✗

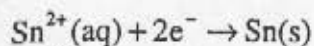
B. zinc ions ✗

(C) magnesium metal ✓

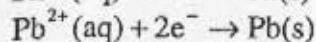
D. zinc metal ✗



33. A student constructs a voltaic cell using tin and lead electrodes. What is the e.m.f. for the spontaneous reaction? The electrode potentials are:



$$E^{\ominus} = -0.14 \text{ V}$$



$$E^{\ominus} = -0.13 \text{ V}$$

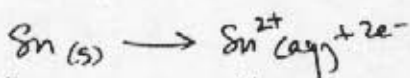
$$\downarrow \\ \Rightarrow E^{\ominus} = +$$

A. 0.27 V

(B) 0.01 V

C. ~~0.01 V~~ ✗

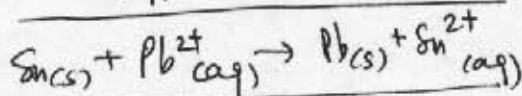
D. ~~0.27 V~~ ✗



$$E^{\ominus}_{\text{ox}} = +0.14 \text{ V}$$

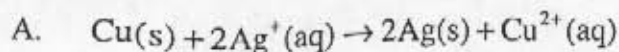


$$E^{\ominus}_{\text{red}} = -0.13 \text{ V}$$

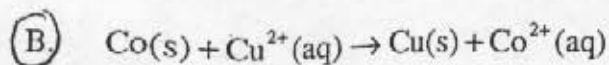


$$E^{\ominus}_{\text{cell}} = 0.14 - 0.13 \\ = +0.01 \text{ V.}$$

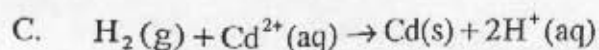
34. For which of the reactions below will ΔG^{\ominus} be the most negative? $\Delta G^{\ominus} = -nFE^{\ominus}$



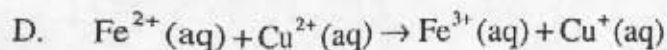
$$E^{\ominus} = 0.46 \text{ V}$$



$$E^{\ominus} = 0.62 \text{ V} \checkmark$$



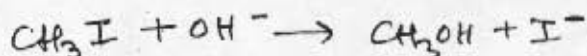
$$E^{\ominus} = -0.40 \text{ V} \text{ ✗}$$



$$E^{\ominus} = -0.61 \text{ V} \text{ ✗}$$

35. The most appropriate conditions for converting iodomethane to methanol are, warming iodomethane with

A. water.



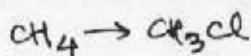
B. dilute sulfuric acid.

(C) dilute aqueous sodium hydroxide. ✓ (S_N2)

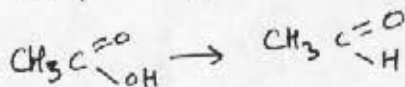
D. silver nitrate solution.

36. For which of the following transformations does the reactive carbon undergo a change in hybridization?

A. alkane to chloroalkane



B. acid to alkanal



C. acid to ester (no change)



(D) alkanol to acid ✓

37. A gaseous alkane and a gaseous alkene are treated separately in the following ways. Which treatment will distinguish between them?

A. They are ignited in excess oxygen.

B. They are passed over heated copper.

(C) They are bubbled through an aqueous solution of bromine. ✓ test for unsaturation

D. They are bubbled through an aqueous solution of propanal.

38. Polymers formed from monomers with the general formula $\text{H}_2\text{C}=\text{CHX}$

(A) have the same percentage of carbon as the monomer. ✓

B. are produced by substitution reactions. ✗

C. contain C=C bonds. ✗ (polymers do not contain C=C)

D. are more reactive than the monomer. ✗

39. How many lines would be expected in the proton NMR spectrum of benzene, C_6H_6 ?

(A) 1 ✓

B. 2

C. 6

D. 42

40. Which one of the following compounds is optically active?

A. $CH_3CH_2CH_2CH_2NH_2$

(B) $CH_3CH_2CH(NH_2)CH_3$ ✓

C. $CH_3CH_2NCH_2CH_3$
H

D. $CH_3CH_2NCH_3$
CH₃

