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INTERNATIONAL BACCALAURÉAT BACHILLERATO — BACCALAUREATE INTERNATIONAL INTERNACIONAL

M99/420/H(1)

CHEMISTRY

Answer Key

Higher Level

Thursday 6 May 1999 (afternoon)

Grade Boundaries:

Paper 1	Grade	1	2	3	4	5	6	7	1 hour
	Mark	0-9	10-15	16-21	22-25	26-28	29-32	≥33 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

INTERNATIONAL BACCALAUREATE

MULTIPLE CHOICE ANALYSIS - QUESTION NUMBER ORDER

SUBJECT: 420 CHEMISTRY HL

10:52:25

38 QUESTIONS 4 CHOICES

QUESTION	A	B	C	D	BLANK	20 % OF TOTAL MARK DIFFICULTY INDEX	DISCRIMINATION INDEX
1	128	2251*	528	175		73.03	.22
2	52	54	34	2940*	2	95.39	.10
3	478	1903*	286	413	1	61.77	.50
4	2012*	271	130	655	13	65.28	.51
5	2499*	248	76	257	2	81.08	.35
6	580	2149*	182	171		69.72	.39
7	376	208	2208*	287	3	71.64	.41
8	576	1914*	105	487		62.10	.46
9	618*	1678	679	99	8	20.05	.03
10	68	66	721	2226*	1	72.22	.31
11	2268*	264	226	324		73.58	.36
12	988	1609*	297	385	3	45.71	.37
13	216	247	2450*	162	6	79.49	.45
14	479	1608*	235	759	1	52.17	.58
15	65	60	117	2819*	1	92.11	.17
16	131	1015	708	1221*	7	39.61	.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	.27
21	1960	365	393	360	4	discarded	.00
22	303	282	372	2118*	6	68.75	.41
23	138	47	145	2751*	1	89.26	.26
24	400	92	2070*	518	1	67.16	.54
25	1671*	241	655	505	10	54.21	.58
26	195	187	2073*	622	5	67.26	.47
27	65	58	110	2847*	2	92.37	.14
28	172	1907*	392	603	8	61.87	.40
29	84	449	207	2336*	6	75.79	.40
30	562	1507	834	163	16	discarded	.00
31	638	1022*	583	825	14	33.16	.35
32	492	228	2108*	237	16	68.39	.42
33	207	2013*	541	289	12	65.96	.51
34	214	2027*	208	610	23	65.76	.37
35	606	511	1691*	255	19	54.86	.32
36	190	415	518	1832*	27	59.44	.61
37	409	171	2251*	222	29	73.03	.44
38	572*	594	622	273	21	51.00	.55
39	1068*	716	1052	214	32	34.65	.53
40	256	2068*	397	317	44	67.09	.52

NUMBER OF CANDIDATES = 3082

1. Which sample has the greatest mass?

Mr

A. 1.0 mol of N_2H_4 32.0 ⇒ 32.0 g

(B.) 2.0 mol of N_2 28.0 ⇒ 56.0 g

C. 3.0 mol of NH_3 17.0 ⇒ 51.0 g

D. 25.0 mol of H_2 2.0 ⇒ 50.0 g

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

Mg	Si	O
24	28	48
24	28	16

1 : 1 : 3

A. MgSiO

B. Mg_2SiO

C. $MgSi_2O$

(D.) $MgSiO_3$

3. What is the mass in grams of one **molecule** of propanol, C_3H_7OH?
(Avogadro's constant 6.0×10^{23} mol^{-1})

C_3H_7OH: 36+8+16 = 60

A. 60

(B.) 1.0×10^{-22}

C. 1.0×10^{-23}

D. 3.6×10^{25}

6.0×10^{23} molecules weigh 60 g

1 molecule weighs $\frac{60\ g/mol}{6.0\times10^{23}\ molecules/mol} \times 1$ molecule

$= 10\times10^{-23}$ g

$= 1.0\times10^{-22}$ g

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

$$2C_2H_3Cl + 5O_2 \rightarrow 4CO_2 + 2H_2O + 2HCl$$

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

∴ n_{O_2} is limiting

5 mol O_2 → 4 mol CO_2

∴ 3.0 " O_2 → $\frac{4.0}{5.0} \times 3.0 = 2.4$ mol O_2

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

5. All isotopes of tin have the same

I. number of protons; ✓

II. number of neutrons; ✗

III. mass number. ✗

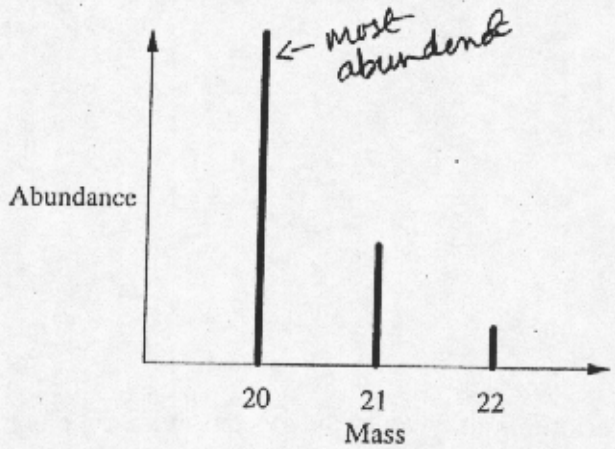
(A.) I only

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 $1s^2 2s^2 2p^6$ (10) $3s^2 3p^1$

B. Z = 14 $3s^2 3p^2$

(C.) Z = 15 ✓ $3s^2 3p^3$ | 1 | 1 | 1 |

D. Z = 16 $3s^2 3p^4$

8. Which element has the lowest first ionization energy?

IE → Increases

↓ decreases

A. Li

(B.) Na ✓

C. Mg

D. Al

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?

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^6 5s^2$

↑ partially filled d-orbital

A. group 6

B. noble gases

C. s block

(D.) d block ✓

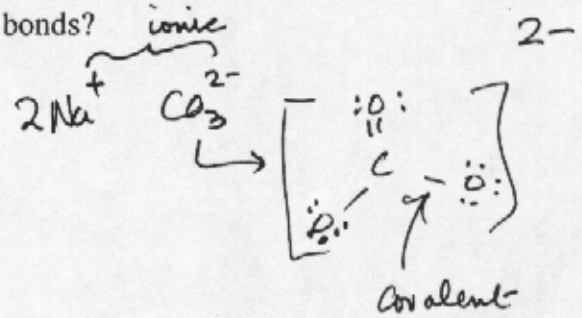
11. Which compound contains both covalent and ionic bonds? ionic

(A.) sodium carbonate, Na_2CO_3 ✓

B. magnesium bromide, $MgBr_2$

C. dichloromethane, CH_2Cl_2

D. ethanoic acid, CH_3COOH

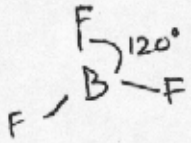


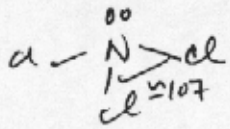
12. In which of the following gaseous molecules are the bond angles equal to 120° ?

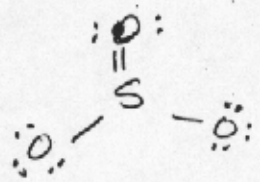
I. BF_3

II. NCl_3

III. SO_3







A. I only

B. I and III only

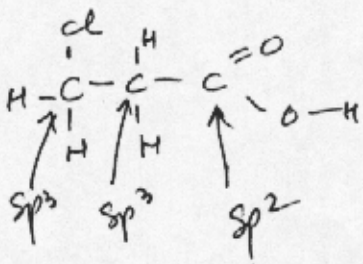
C. II and III only

D. I, II and III

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

$$\underset{1}{H_2Cl\,C}—\underset{2}{CH_2}—\underset{3}{COOH}\ ?$$

	1	*2*	*3*
A.	sp^2	sp^2	sp^2
B.	sp^3	sp^2	sp
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

B. H_2O, H_2S

C. C_2H_6, C_3H_8

D. CH_3OCH_3, CH_3CH_2OH

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 cm^3 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? ($R = 82.05\ cm^3\ atm\ K^{-1}\ mol^{-1}$) → 35+273 = 308 K

A. $\frac{1.42 \times 82.05 \times 35}{0.25 \times 0.85}$ ✗

B. $\frac{1.42 \times 82.05 \times 308}{0.25 \times 0.85}$

C. $\frac{1.42 \times 250 \times 0.85}{82.05 \times 308}$

(D.) $\frac{1.42 \times 82.05 \times 308}{250 \times 0.85}$ ✓

$PV = nRT$

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

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

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

17. A mixture of 0.40 mol of N_2, 0.20 mol of O_2 and 0.20 mol of CO_2 has a total pressure of 1.6 atmospheres. What is the partial pressure of O_2 in atmospheres?

A. 0.20

B. 0.25

C. 0.32

(D.) 0.40 ✓

$P_{O_2} = X_{O_2} \times P_{tot}$ ← 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;

$$SOCl_2(l) + H_2O(l) \rightarrow 2HCl(g) + SO_2(g)$$

Use the following data to calculate $\Delta H^{\ominus}$ for this reaction.

	$SOCl_2(l)$	$H_2O(l)$	$HCl(g)$	$SO_2(g)$
$\Delta H_f^{\ominus}$ (kJ mol^{-1})	–245.6	–285.8	–92.3	–296.8

A. –142.3

B. –50.0

(C.) +50.0 ✓

D. +142.3

$\Delta H^{\circ}_{rxn} = \sum \Delta H^{\circ}_{f,P} - \sum \Delta H^{\circ}_{f,R}$

$= [2(-92.3) + (-296.8)] - [(-245.6) + (-285.8)]$

$= -481.4 - (-531.4)$

$= -481.4 + 531.4 = +50.0$

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}

$Q = mc\Delta T$

$200\,J = 10\,g \times c \times 50\,^{\circ}C$

$\therefore c = \frac{200\ J}{500\ g\ ^{\circ}C}$

$= 0.40\ J\ g^{-1}\ ^{\circ}C^{-1}$

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

A. $Na_2O(s) + H_2O(l) \rightarrow 2Na^+(aq) + 2OH^-(aq)$ (s) + (l) → (aq) + (aq)

B. $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ 2(g) → (s) ✗

C. $H_2(g) + I_2(g) \rightarrow 2HI(g)$ 2(g) → 2(g) ✗

(D.) $C(s) + CO_2(g) \rightarrow 2CO(g)$ ✓✓

1 (g) 2 (g)

21. For the reaction;

$$6HC{\equiv}CH(g) \rightarrow C_6H_6(g)$$

$\Delta H^{\ominus} = -597.3$ kJ and $\Delta S^{\ominus} = -0.33$ 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.

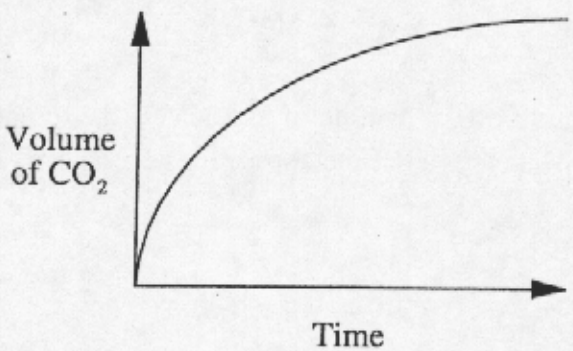
B. is spontaneous at 300K and becomes non-spontaneous at lower temperatures.

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

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

$\Delta G = \Delta H - T\Delta S$
$= -597.3 - 300(-0.33)$
$= -597.3 + 99$
$= -498.3$ kJ

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.

C. fastest step.

(D.) slowest step. ✓

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

$$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$$

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

$[NO_2]$ / mol dm^{-3}	$[CO]$ / mol dm^{-3}	Rate / mol dm^{-3} s^{-1}
0.10 → ×3	0.10 constant	1.0×10^{-6}
0.30 constant	0.10 → ×3	9.0×10^{-6} (×9)
0.30	0.30	9.0×10^{-6} same

$\therefore \propto [NO_2]^2$; $\propto [CO]^0$

A. Rate $= k[NO_2][CO]$

$\therefore$ rate $= k[NO_2]^2$

B. Rate $= k[CO]^2$

(C.) Rate $= k[NO_2]^2$ ✓

D. Rate $= k[NO_2]^3$

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

(A.) $>> 1$ ✓

B. $<< 1$

C. $= 1$

D. $= 0$

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

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H^{\ominus} = -197 \text{ kJ}$$

(+heat ↓)

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 ⇒ low vol ⇒ products occupying less vol. favored

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;

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

What is the equilibrium expression for this reaction?

A. $[CS_2][H_2]/[CH_4][H_2S]$ ✗

B. $4[CS_2][H_2]/2[CH_4][H_2S]$ ✗

C. $[CS_2]+4[H_2]/[CH_4]+2[H_2S]$ ✗ ✗

(D.) $[CS_2][H_2]^4/[CH_4][H_2S]^2$ ✓

$$K_c = \frac{[CS_2][H_2]^4}{[CH_4][H_2S]^2}$$

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

A. hydrochloric acid — strong acid ⇒ strong electrolyte

(B.) ethanoic acid — weak acid ⇒ weak electrolyte

C. sodium hydroxide — strong base ⇒ strong electrolyte

D. ammonium chloride — salt ⇒ " "

29. In the equilibrium below;

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

Acid base conj base Acid

which species represent a conjugate acid–base pair?

A. CH_3COOH / H_2O

B. CH_3COO^- / H_3O^+

C. H_2O / CH_3COO^-

(D.) H_3O^+ / H_2O ✓

30. Which of the following combinations produce a buffer solution when equal volumes are mixed?

I. 0.1M HCl and 0.1M NH_4Cl S.A. (HCl) + W.A. (NH_4^+) ✗

II. 0.1M HCl and 0.2M NH_3 → $NH_3 + H^+ \rightarrow NH_4^+$ ✓

0.20 0.10 — 0.10

III. 0.1M NH_3 and 0.1M NH_4Cl 0.10 — —

↳ NH_3 / NH_4^+ : 0.10 each ✓

A. I only ✗

B. III only ✗

(C.) II and III only ✓

D. I, II and III

31. In which reaction below does the **first** species listed react as a Lewis acid?

↳ e⁻ pair acceptor

A. $H_2O + HPO_4^{2-} \rightleftharpoons H_2PO_4^- + OH^-$

(B.) $H^+ + NH_3 \rightleftharpoons NH_4^+$ ✓

C. $NO_2^- + H_3O^+ \rightleftharpoons HNO_2 + H_2O$

D. $NH_4^+ + HS^- \rightleftharpoons H_2S + NH_3$

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 ✗

$Mg_{(s)} + Zn^{2+}_{(aq)} \rightarrow Zn_{(s)} + Mg^{2+}_{(aq)}$

$Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow Cu_{(s)} + Zn^{2+}_{(aq)}$

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:

$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$ $\quad E^\ominus = -0.14$ V

$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ $\quad E^\ominus = -0.13$ V

⇓

$\Rightarrow E^\circ = +$

A. 0.27 V

B. 0.01 V

C. −0.01 V ✗

D. −0.27 V ✗

$Sn_{(s)} \rightarrow Sn^{2+}_{(aq)} + 2e^-$ $\quad E^\circ_{ox} = +0.14$ V

$Pb^{2+}_{(aq)} + 2e^- \rightarrow Pb_{(s)}$ $\quad E^\circ_{red} = -0.13$ V

$Sn_{(s)} + Pb^{2+}_{(aq)} \rightarrow Pb_{(s)} + Sn^{2+}_{(aq)}$

$E^\circ_{cell} = 0.14 - 0.13$

$= +0.01$ V.

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

A. $Cu(s) + 2Ag^+(aq) \rightarrow 2Ag(s) + Cu^{2+}(aq)$ $\quad E^\ominus = 0.46$ V

B. $Co(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Co^{2+}(aq)$ $\quad E^\ominus = 0.62$ V ✓

C. $H_2(g) + Cd^{2+}(aq) \rightarrow Cd(s) + 2H^+(aq)$ $\quad E^\ominus = -0.40$ V ✗

D. $Fe^{2+}(aq) + Cu^{2+}(aq) \rightarrow Fe^{3+}(aq) + Cu^+(aq)$ $\quad E^\ominus = -0.61$ V ✗

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

A. water. $CH_3I + OH^- \longrightarrow CH_3OH + I^-$

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 $CH_4 \rightarrow CH_3Cl$

B. acid to alkanal $CH_3C(=O)OH \rightarrow CH_3C(=O)H$

C. acid to ester (no change) $CH_3CH_2OH \longrightarrow CH_3C(=O)OH$

(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 $H_2C=CHX$

(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

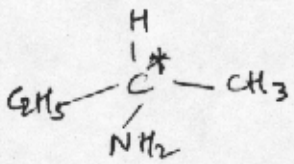
C. 6

D. 42

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

A. $CH_3CH_2CH_2CH_2NH_2$

(B.) $CH_3CH_2\underset{\underset{NH_2}{|}}{C}HCH_3$ ✓



C. $CH_3CH_2\underset{\underset{H}{|}}{N}CH_2CH_3$

D. $CH_3CH_2\underset{\underset{CH_3}{|}}{N}CH_3$