

ABBREVIATIONS AND SYMBOLS			
amount of substance	<i>n</i>	equilibrium constant	<i>K</i>
ampere	A	Faraday constant	<i>F</i>
atmosphere	atm	formula molar mass	<i>M</i>
atomic mass unit	u	free energy	<i>G</i>
atomic molar mass	<i>A</i>	frequency	
Avogadro constant	N_A	gas constant	<i>R</i>
Celsius temperature	°C	gram	g
centi- prefix	c	hour	h
coulomb	C	joule	J
electromotive force	<i>E</i>	kelvin	K
energy of activation	E_a	kilo- prefix	k
enthalpy	<i>H</i>	liter	L
entropy	<i>S</i>	measure of pressure	mmHg
		milli- prefix	m
		molal	<i>m</i>
		molar	M
		mole	mol
		Planck's constant	<i>h</i>
		pressure	<i>P</i>
		rate constant	<i>k</i>
		second	s
		speed of light	<i>c</i>
		temperature, K	<i>T</i>
		time	<i>t</i>
		volt	V
		volume	V

CONSTANTS
$R = 8.314 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
$R = 0.0821 \text{ L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$
$1 F = 96,500 \text{ C}\cdot\text{mol}^{-1}$
$1 F = 96,500 \text{ J}\cdot\text{V}^{-1}\cdot\text{mol}^{-1}$
$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$
$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$
$c = 2.998 \times 10^8 \text{ m}\cdot\text{s}^{-1}$

PERIODIC TABLE OF THE ELEMENTS

1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
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
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	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 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 181.0	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89 Ac 227.0	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)	114 (289)					

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	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 (260)

DIRECTIONS

- When you have selected your answer, blacken the corresponding space on the answer sheet with a soft, black #2 pencil. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark very carefully.
- Make no marks in the test booklet. Do all calculations on scratch paper provided by your examiner.
- There is only one correct answer to each question. Any questions for which more than one response has been blackened will not be counted.
- Your score is based solely on the number of questions you answer correctly. It is to your advantage to answer every question.
- The best strategy is to arrive at your own answer to a question before looking at the choices. Otherwise, you may be misled by plausible, but incorrect, responses.

1. Which element reacts most rapidly with water at 25 °C to produce a gas?
(A) aluminum (B) carbon
(C) lithium (D) phosphorus
2. Which is the best procedure to follow if a student spills several drops of concentrated HCl on his hand?
(A) Cover the area with solid sodium hydrogen carbonate.
(B) Rinse with large amounts of cold water.
(C) Wash with concentrated sodium hydroxide solution.
(D) Wrap the hand with sterile gauze.
3. Which pair of substances can be combined to produce ammonia gas?
1. $(\text{NH}_4)_2\text{SO}_4(s)$ and $\text{NaOH}(aq)$
2. $\text{NH}_3(aq)$ and $\text{HCl}(aq)$
(A) 1 only (B) 2 only
(C) both 1 and 2 (D) neither 1 nor 2
4. What products result when equal volumes of equimolar aqueous solutions of copper(II) sulfate and barium hydroxide are mixed?
(A) $\text{Ba}^{2+}(aq)$, $\text{Cu}^{2+}(aq)$, $\text{OH}^-(aq)$, and $\text{SO}_4^{2-}(aq)$
(B) $\text{Cu}(\text{OH})_2(s)$, $\text{Ba}^{2+}(aq)$, and $\text{SO}_4^{2-}(aq)$
(C) $\text{BaSO}_4(s)$, $\text{Cu}^{2+}(aq)$, and $\text{OH}^-(aq)$
(D) $\text{BaSO}_4(s)$ and $\text{Cu}(\text{OH})_2(s)$
5. Which statement about silicon is *false*?
(A) It is a metalloid.
(B) It behaves as a semiconductor when pure.
(C) It is extremely rare in the earth's crust.
(D) It has a smaller atomic radius than aluminum.
6. A standard HCl solution is titrated to a pink phenolphthalein endpoint by adding a NaOH solution while stirring. If a solution becomes pink throughout but loses its color upon standing for a short time, what should be done to restore the color?
(A) Add more phenolphthalein indicator.
(B) Add an additional drop of NaOH solution.
(C) Add an additional drop of HCl solution.
(D) Stir more vigorously.
7. A sample of gas in a small test tube produces a pop when a burning splint is inserted. Which gas could it be?
(A) H_2 (B) O_2 (C) Cl_2 (D) NO
8. Electrolysis is used commercially to isolate which metal(s)?
1. Al 2. Fe
(A) 1 only (B) 2 only
(C) both 1 and 2 (D) neither 1 nor 2
9. An oxide of manganese contains 2.29 g of manganese per gram of oxygen. What is the empirical formula of this compound?
(A) MnO (B) MnO_2
(C) Mn_2O_3 (D) MnO_3
10. A heterogeneous system is produced when 0.040 moles of solid NaCl is added to 0.10 L of 0.10 M $\text{Pb}(\text{NO}_3)_2$. Which ion is present in the aqueous phase at the highest concentration?
(A) Cl^- (B) NO_3^-
(C) Pb^{2+} (D) Na^+
11. Which expression gives the fraction by mass of nitrogen in ammonium dihydrogen phosphate?
(A) 14 / 115 (B) 28 / 115
(C) 28 / 132 (D) 14 / 210

12. Ethanol burns in excess oxygen to form $\text{CO}_2(g)$ and $\text{H}_2\text{O}(g)$ according to this balanced equation.
- $$\text{C}_2\text{H}_5\text{OH}(g) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(g)$$
- What value is closest to the volume of $\text{CO}_2(g)$, measured at 200K and 1 atm, produced from the combustion of 0.25 mol of $\text{C}_2\text{H}_5\text{OH}(g)$?

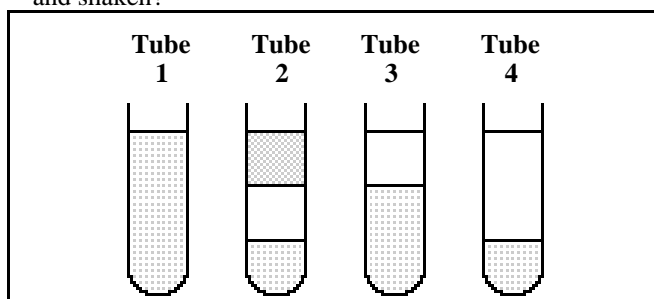
- (A) 5 L (B) 8 L
(C) 10 L (D) 15 L

13. Adipic acid, $\text{HOOC}(\text{CH}_2)_4\text{COOH}$, is used in making nylon. What is the total number of atoms in 1.0 g of adipic acid?

Molar Mass, $\text{g}\cdot\text{mol}^{-1}$	
adipic acid	146.26

- (A) 20 (B) 4.1×10^{21}
(C) 8.2×10^{22} (D) 7.2×10^{24}

14. Hexane, C_6H_{14} , is immiscible with water and ethanol. Water and ethanol are miscible. C_6H_{14} has the lowest density. Which diagram represents the results when equal volumes of these three liquids are placed in a test tube and shaken?



- (A) 1 (B) 2 (C) 3 (D) 4

15. $5\text{H}_2\text{C}_2\text{O}_4(aq) + 2\text{MnO}_4^-(aq) + 6\text{H}^+(aq) \rightarrow 2\text{Mn}^{2+}(aq) + 10\text{CO}_2(g) + 8\text{H}_2\text{O}(l)$

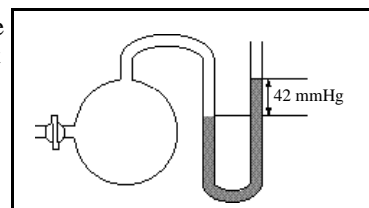
Oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$, reacts with permanganate ion according to the balanced equation above. How many mL of 0.0154 M KMnO_4 solution are required to react with 25.0 mL of 0.0208 M $\text{H}_2\text{C}_2\text{O}_4$ solution?

- (A) 13.5 mL (B) 18.5 mL
(C) 33.8 mL (D) 84.4 mL

16. A sample of neon gas has a volume of 248 mL at $30.^\circ\text{C}$ and a certain pressure. What volume would it occupy if it were heated to $60.^\circ\text{C}$ at the same pressure?

- (A) 226 mL (B) 273 mL
(C) 278 mL (D) 496 mL

17. A gas is collected in the flask shown here. What is the pressure exerted by the gas if the atmospheric pressure is 735 mmHg?



- (A) 42 mmHg (B) 693 mmHg
(C) 735 mmHg (D) 777 mmHg

18. Helium is often found with methane, CH_4 . How do the diffusion rates of helium and methane compare at the same temperature? Helium diffuses

- (A) sixteen times as fast as methane.
(B) four times as fast as methane.
(C) twice as fast as methane.
(D) at the same rate as methane.

19. Which substance contains individual molecules in the solid?

- (A) graphite (B) iodine
(C) mercury (D) silicon carbide

20. The compounds C_3H_8 , $\text{CH}_3\text{CH}_2\text{OH}$, and CH_3OCH_3 have very similar molar masses. When they are arranged in order of *increasing* strength of their intermolecular forces, what is the correct order?

- (A) C_3H_8 , CH_3OCH_3 , $\text{CH}_3\text{CH}_2\text{OH}$
(B) $\text{CH}_3\text{CH}_2\text{OH}$, CH_3OCH_3 , C_3H_8
(C) CH_3OCH_3 , C_3H_8 , $\text{CH}_3\text{CH}_2\text{OH}$
(D) $\text{CH}_3\text{CH}_2\text{OH}$, C_3H_8 , CH_3OCH_3

21. Which property does *not* indicate strong intermolecular forces?

- (A) high enthalpy of vaporization
(B) high viscosity
(C) high critical temperature
(D) high vapor pressure

22. Calculate the amount of energy necessary to heat a 2.5 g ice cube from 0°C to 23°C .

Values for H_2O	
C_p	$4.18 \text{ J}\cdot\text{g}^{-1}\cdot^\circ\text{C}^{-1}$
H_{fusion}	$3.4 \times 10^2 \text{ J}\cdot\text{g}^{-1}$

- (A) 240 J (B) 850 J
(C) 1100 J (D) 3700 J

23. Estimate H for this reaction.
 $\text{H}_2(g) + \text{Cl}_2(g) \rightarrow 2\text{HCl}(g)$

Bond Energies, $\text{kJ}\cdot\text{mol}^{-1}$	
H–H	436
Cl–Cl	243
H–Cl	431

- (A) 1110 kJ (B) 248 kJ
 (C) –183 kJ (D) –248 kJ
24. Which reaction occurs with an increase in entropy?
- (A) $2\text{C}(s) + \text{O}_2(g) \rightarrow 2\text{CO}(g)$
 (B) $2\text{H}_2\text{S}(g) + \text{SO}_2(g) \rightarrow 3\text{S}(s) + 2\text{H}_2\text{O}(g)$
 (C) $4\text{Fe}(s) + 3\text{O}_2(g) \rightarrow 2\text{Fe}_2\text{O}_3(s)$
 (D) $\text{CO}(g) + 2\text{H}_2(g) \rightarrow \text{CH}_3\text{OH}(l)$
25. Consider this reaction.
 $2\text{N}_2\text{H}_4(l) + \text{N}_2\text{O}_4(l) \rightarrow 3\text{N}_2(g) + 4\text{H}_2\text{O}(g) \quad H = -1078 \text{ kJ}$
 How much energy is released by this reaction during the formation of 140. g of $\text{N}_2(g)$?
- (A) 1078 kJ (B) 1797 kJ
 (C) 3234 kJ (D) 5390 kJ
26. Use the information in the table to calculate the enthalpy of this reaction.
 $\text{C}_2\text{H}_6(g) + 7/2\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$
- | Reaction | H_f° , $\text{kJ}\cdot\text{mol}^{-1}$ |
|--|---|
| $2\text{C}(s) + 3\text{H}_2(g) \rightarrow \text{C}_2\text{H}_6(g)$ | –84.7 |
| $2\text{C}(s) + \text{O}_2(g) \rightarrow \text{CO}_2(g)$ | –393.5 |
| $\text{H}_2(g) + 1/2\text{O}_2(g) \rightarrow \text{H}_2\text{O}(l)$ | –285.8 |
- (A) –764 kJ (B) –1560 kJ
 (C) –1664 kJ (D) –3120 kJ
27. For the reaction $\text{PCl}_3(g) + \text{Cl}_2(g) \rightarrow \text{PCl}_5(g)$, $H^\circ = -86 \text{ kJ}$. Under what temperatures is this reaction expected to be spontaneous?
- (A) no temperatures (B) high temperatures only
 (C) all temperatures (D) low temperatures only
28. The radioisotope, N-13, has a half-life of 10.0 minutes. What is the rate constant for the radioactive decay of N-13?
- (A) 0.0301 min^{-1} (B) 0.0693 min^{-1}
 (C) 0.100 min^{-1} (D) 6.93 min^{-1}

29. For the reaction $2\text{C}_2\text{H}_6(g) + 7\text{O}_2(g) \rightarrow 4\text{CO}_2(g) + 6\text{H}_2\text{O}(l)$, the rate of disappearance of $\text{C}_2\text{H}_6(g)$
- (A) equals the rate of disappearance of $\text{O}_2(g)$.
 (B) is seven times the rate of disappearance of $\text{O}_2(g)$.
 (C) is twice the rate of appearance of $\text{CO}_2(g)$.
 (D) is one-third the rate of appearance of $\text{H}_2\text{O}(l)$.

30. The rate law for a certain reaction is found to be:
 $\text{rate} = k [\text{A}] [\text{B}]^2$

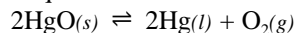
How will the rate of this reaction compare if the concentration of **A** is doubled and the concentration of **B** is halved? The rate will

- (A) remain the same.
 (B) be double the original rate.
 (C) be triple the original rate.
 (D) be one-half the original rate.
31. Use the experimental data in this table to determine the rate law for the reaction of hydrogen iodide, HI, with ethyl iodide, $\text{C}_2\text{H}_5\text{I}$.

[HI], M	$[\text{C}_2\text{H}_5\text{I}]$, M	Rate, $\text{M}\cdot\text{s}^{-1}$
0.010	0.010	1.2×10^{-5}
0.010	0.020	2.4×10^{-5}
0.020	0.030	7.2×10^{-5}

- (A) $\text{rate} = k [\text{HI}]$
 (B) $\text{rate} = k [\text{HI}] [\text{C}_2\text{H}_5\text{I}]$
 (C) $\text{rate} = k [\text{HI}]^2 [\text{C}_2\text{H}_5\text{I}]$
 (D) $\text{rate} = k [\text{HI}]^2 [\text{C}_2\text{H}_5\text{I}]^3$
32. For the reaction $\text{NO}_2(g) + \text{CO}(g) \rightarrow \text{NO}(g) + \text{CO}_2(g)$ at temperatures below 500 K, the rate law is $\text{rate} = k [\text{NO}_2]^2$. Which mechanism is consistent with this information?
- Mechanism 1 $\text{NO}_2 + \text{NO}_2 \rightarrow \text{NO}_3 + \text{NO}$ slow
 $\text{CO} + \text{NO}_3 \rightarrow \text{CO}_2 + \text{NO}_2$ fast
- Mechanism 2 $\text{NO}_2 + \text{NO}_2 \rightleftharpoons \text{NO}_3 + \text{NO}$ fast
 $\text{CO} + \text{NO}_3 \rightarrow \text{CO}_2 + \text{NO}_2$ slow
- (A) 1 only (B) 2 only
 (C) either 1 or 2 (D) neither 1 nor 2

33. Mercury(II) oxide, HgO, is decomposed upon heating according to this equation.



What is the equilibrium expression for this process?

- (A) $K = \frac{[\text{Hg}]^2[\text{O}_2]}{[\text{HgO}]^2}$ (B) $K = \frac{[\text{Hg}][\text{O}_2]}{[\text{HgO}]}$
 (C) $K = [\text{Hg}][\text{O}_2]$ (D) $K = [\text{O}_2]$

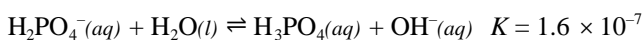
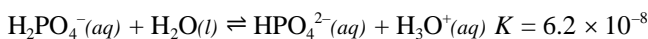
34. Consider this reaction.



What conditions of temperature and pressure will produce the highest yield of NOCl at equilibrium?

- | | <i>T</i> | <i>P</i> |
|-----|----------|----------|
| (A) | high | high |
| (B) | high | low |
| (C) | low | high |
| (D) | low | low |

35. The dihydrogen phosphate ion undergoes these reactions in water.



What is the conjugate base of H₂PO₄⁻?

- (A) HPO₄²⁻(aq) (B) H₂O(l)
 (C) OH⁻(aq) (D) H₃PO₄(aq)

36. What is the pH of a 0.15 M solution of formic acid, HCOOH?

Formic Acid	<i>K_A</i>
HCOOH	1.9 × 10 ⁻⁴

- (A) 1.49 (B) 2.27
 (C) 3.72 (D) 4.55
37. Which of these mixtures constitute buffer solutions?

Mixture 1 25 mL of 0.10 M HNO₃ and
 25 mL of 0.10 M NaNO₃

Mixture 2 25 mL of 0.10 M HC₂H₃O₂ and
 25 mL of 0.10 M NaOH

- (A) 1 only (B) 2 only
 (C) both 1 and 2 (D) neither 1 nor 2

38. Which salt gives the most acidic 0.1 M solution in water?

- (A) NaCl (B) NaNO₂
 (C) NH₄Cl (D) NH₄NO₂

39. What is the solubility of magnesium carbonate, MgCO₃, in water at 25 °C?

Data for MgCO ₃	
molar mass	84 g·mol ⁻¹
<i>K_{sp}</i> at 25 °C	6.8 × 10 ⁻⁶

- (A) 0.22 g·L⁻¹ (B) 2.6 × 10⁻³ g·L⁻¹
 (C) 3.1 × 10⁻⁵ g·L⁻¹ (D) 8.1 × 10⁻⁸ g·L⁻¹

40. For which substance is the oxidation number of vanadium the same as that in the VO₃⁻ ion?

- (A) VN (B) VCl₃
 (C) VOSO₄ (D) VF₅

41. $__ \text{ClO}_3^- + __ \text{I}^- + __ \text{H}^+ \rightarrow __ \text{Cl}^- + __ \text{I}_2 + __ \text{H}_2\text{O}$

When this equation is balanced with whole number coefficients, what is the H⁺/I₂ coefficient ratio?

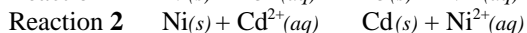
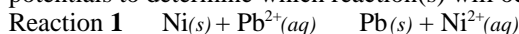
- (A) 2/1 (B) 3/1
 (C) 6/1 (D) some other ratio

42. Use the information in the table to calculate *E*^o for this reaction.

Reaction		<i>E</i> ^o
Ga(s) + 3Tl ⁺ (aq)	3Tl(s) + Ga ³⁺ (aq)	
Ga ³⁺ (aq) + 3e ⁻	Ga(s)	-0.529 V
Tl ⁺ (aq) + e ⁻	Tl(s)	-0.336 V

- (A) 0.479 V (B) 0.193 V
 (C) -0.193 V (D) -0.479 V

43. Nickel metal is added to a solution containing 1.0 M Pb²⁺(aq) and 1.0 M Cd²⁺(aq). Use the standard reduction potentials to determine which reaction(s) will occur.



Reaction		<i>E</i> ^o
Pb ²⁺ (aq) + 2e ⁻	Pb(s)	-0.13 V
Ni ²⁺ (aq) + 2e ⁻	Ni(s)	-0.23 V
Cd ²⁺ (aq) + 2e ⁻	Cd(s)	-0.40 V

- (A) 1 only (B) 2 only
 (C) both 1 and 2 (D) neither 1 nor 2

**U.S. NATIONAL CHEMISTRY OLYMPIAD
2002 LOCAL SECTION EXAM — KEY**

Number	Answer	Number	Answer	Number	Answer
1.	C	21.	D	41.	A
2.	B	22.	C	42.	B
3.	A	23.	C	43.	A
4.	D	24.	A	44.	C
5.	C	25.	B	45.	D
6.	B	26.	B	46.	C
7.	A	27.	D	47.	A
8.	A	28.	B	48.	B
9.	C	29.	D	49.	C
10.	D	30.	D	50.	B
11.	A	31.	B	51.	D
12.	B	32.	A	52.	D
13.	C	33.	D	53.	C
14.	C	34.	C	54.	A
15.	A	35.	A	55.	D
16.	B	36.	B	56.	A
17.	D	37.	D	57.	C
18.	C	38.	C	58.	B
19.	B	39.	A	59.	D
20.	A	40.	D	60.	A

