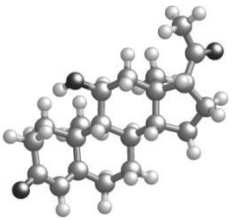


Chem!stry

Name: …… **( )**

Class: ……

Date: …… **/** …… **/** ……

Chemistry Olympiad Training for Secondary School Level – Part Four

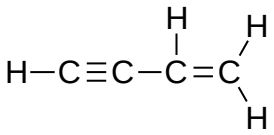
1. The K_a value of an acid is given by the equation:

$$K_a = \frac{[H^+] \times [A^-]}{[HA]}$$

Which one of the following acids is the strongest acid?

A	Oxalic acid	$H_2C_2O_4$	$Ka = 5.90 \times 10^{-2}$
B	Hydrofluoric acid	HF	$Ka = 7.20 \times 10^{-4}$
C	Ethanoic acid	CH_3COOH	$Ka = 1.76 \times 10^{-5}$
D	Phenol	C_6H_5OH	$Ka = 1.60 \times 10^{-10}$

2. The structural formula of but-3-yn-1-ene is given below:



How many π-bonding electrons are there in a single molecule of but-3-yn-1-ene?

A 3 **B** 6

C 10 **D** 20

3. Phenolphthalein is a common indicator that is used for acid-base titrations. Phenolphthalein's percentage composition by mass is given below:

C = 75.46 %

H = 4.43 %

O = 20.11 %

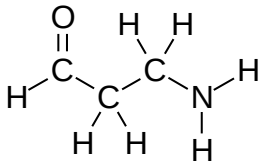
What is the empirical formula of phenolphthalein?

A $C_7H_3O_2$ **B** $C_{10}H_7O_2$

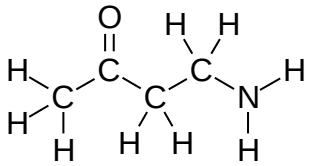
C $C_{15}H_4O_2$ **D** $C_5H_2O_3$

4. Which molecule contains both an amine and a ketone?

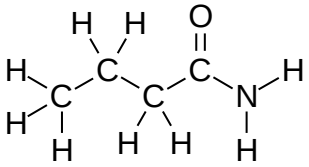
A



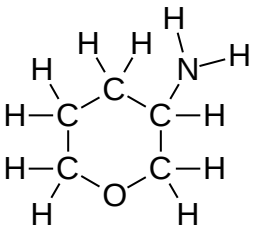
B



C



D



5. Tellurium has a lower atomic number than iodine, but it has a higher relative atomic mass than iodine. This is because:

A Tellurium has more electrons than iodine.

B Tellurium has more isotopes than iodine.

C One of the isotopes of tellurium has more neutrons than one of the isotopes of iodine.

D The main isotopes of tellurium have more nucleons than the main isotopes of iodine.

6. How many electrons are transferred from $10I^-$ to $2MnO_4^-$ ions in the following redox reaction?

$$2\ MnO_4^-(aq)\ +\ 16\ H^+(aq)\ +\ 10\ I^-\ \rightarrow\ 2\ Mn^{2+}(aq)\ +\ 5\ I_2(aq)\ +\ 8\ H_2O(l)$$

A 5 **B** 8

C 10 **D** 16

7. Gas **X** dissociates on heating to set up the following equilibrium:

$$X(g)\ \rightleftharpoons\ Y(g)\ +\ Z(g)$$

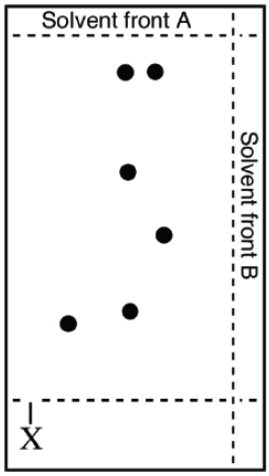
A quantity of gas **X** was heated at a constant pressure, p, at a certain temperature. The equilibrium partial pressure of **X** was found to be $^1/_7\ p$. What is the equilibrium constant, K_p, at this temperature?

A $^6/_7\ p$ **B** $^9/_7\ p$

C $6\ p$ **D** $9\ p$

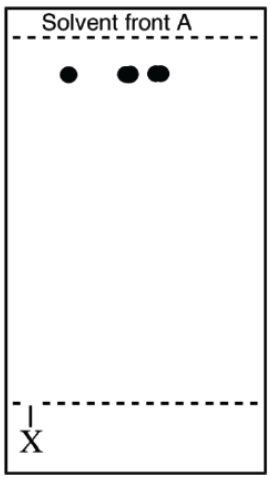
8. Thin layer chromatography (TLC) is used to separate mixtures of compounds based upon the different polarities of the compounds. This is done based on their interactions with the polar stationary phase and the less polar mobile phase.

A mixture of compounds is placed on the TLC plate at the position marked "X". Through capillary attraction, solvent **A** moves up the plate until it reaches the point shown. The plate is then dried, rotated 90° and the process repeated using solvent **B** to give the following result:

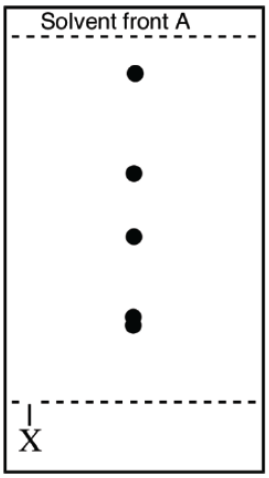


Which of the following plates would be the one that you would expect to obtain after using **only** solvent **A** as the mobile phase?

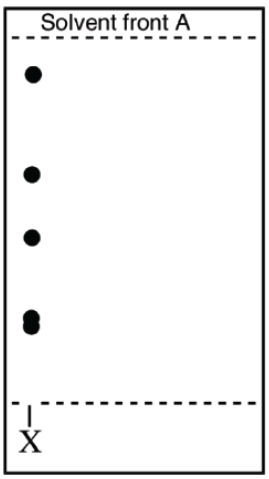
A



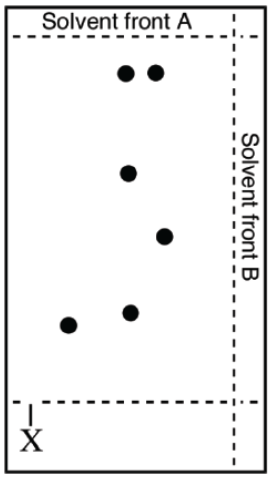
B



C



D



9. A *hypergolic* fuel system consisting of monomethylhydrazine, CH_3NHNH_2, and dinitrogen tetroxide, N_2O_4, (both liquids) is commonly used to propel space vehicles. The two reactants are combined stoichiometrically so that CO_2, H_2O and N_2 are the only products formed (all gases under the same reaction conditions). How many moles of gas are produced from 100 mol of CH_3NHNH_2?

A 125 **B** 225

C 400 **D** 625

10. Pure water undergoes self-ionization according to the equation:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The equilibrium constant for the reaction is:

1.0×10^{-14} at 25°C and 5.5×10^{-13} at 100°C.

Which one of the following statements is correct?

A At 100°C, the pH of pure water is less than 7.0, but the $[H^+] = [OH^-]$.

B At 100°C, the pH of pure water is less than 7.0, and therefore $[H^+] > [OH^-]$.

C At 100°C, the pH of pure water is greater than 7.0, and therefore $[OH^-] > [H^+]$.

D At 100°C, the pH of pure water must be 7.0, and the $[H^+] = [OH^-]$.

11. In which one of the following compounds does manganese exist in the lowest oxidation state?

A Mn_2O_7 **B** $Mn(CH_3COO)_2{\cdot}4H_2O$

C $KMnO_4$ **D** MnO_2F

12. The enthalpy change of formation ($\Delta H_f°$) for a species at 298 K is defined as the enthalpy change that accompanies the formation of one mole of a substance from its constituent elements in their standard states. Which one of the following species has $\Delta H_f° = 0$ kJ mol^{-1}?

A $H_2O(l)$ **B** Na(s)

C $CO_2(g)$ **D** $O_3(g)$

13. A Chemist requires 16.0 mol of liquid ethanol, C_2H_5OH, for a chemical reaction. What volume of ethanol should she use? The density of ethanol is 0.789 g cm^{-3}.

A 0.581 dm^3 **B** 0.690 dm^3

C 0.934 dm^3 **D** 1.88 dm^3

14. 2,4,6-trinitrotoluene (TNT, $C_7H_5N_3O_6$) can be used in synthetic organic chemistry, however, its use is limited because of its highly explosive nature. Upon detonation, TNT decomposes as a mixture of the following reactions:

$$2\ C_7H_5N_3O_6 \rightarrow 3\ N_2 + 5\ H_2O + 7\ CO + 7\ C$$

$$2\ C_7H_5N_3O_6 \rightarrow 3\ N_2 + 5\ H_2 + 12\ CO + 2\ C$$

When 20 mol of TNT was exploded with complete conversion into products, 30 mol of hydrogen gas was produced. How many moles of carbon monoxide were also produced?

A 28 **B** 49

C 72 **D** 100

15. For a spontaneous reaction to occur at constant temperature and pressure, the Gibbs free energy (ΔG) must be negative. The Gibbs free energy combines two thermodynamic parameters into the Gibbs equation: $\Delta G = \Delta H - T\Delta S$, where ΔH is the change in enthalpy and ΔS is the change in entropy. What conditions of ΔH and ΔS for a chemical reaction will always give a spontaneous reaction?

A ΔH positive, ΔS positive.

B ΔH positive, ΔS negative.

C ΔH negative, ΔS positive.

D ΔH negative, ΔS negative.

16. Which one of the following species is both a hydrogen-bond donor and a hydrogen-bond acceptor?

A CH_3OCH_3 **B** HI

C CH_3OH **D** CH_4

17. The most common batteries used in cars are lead-acid batteries that can be discharged and recharged according to the following equation:

$$Pb(s) + PbO_2(s) + 2\,H_2SO_4(aq) \underset{\text{recharge}}{\overset{\text{discharge}}{\rightleftharpoons}} 2\,PbSO_4(aq) + 2\,H_2O(l)$$

When discharging, which species is the reducing agent?

A Pb(s) **B** $PbO_2(s)$

C $SO_4^{2-}(aq)$ **D** $PbSO_4(aq)$

18. By referring to the standard reduction potentials below, which one of the species listed is the best oxidising agent?

$$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s) \quad E^\circ = +0.34\ V$$

$$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s) \quad E^\circ = -0.23\ V$$

$$Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s) \quad E^\circ = -0.40\ V$$

$$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s) \quad E^\circ = -0.44\ V$$

A Cd(s) **B** $Cu^{2+}(aq)$

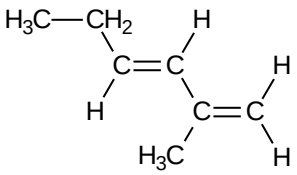
C $Fe^{2+}(aq)$ **D** Ni(s)

19. Which one of the following species does **not** have eight valence electrons surrounding the central atom?

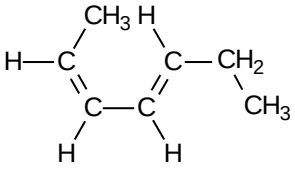
A CCl_4 **B** NH_4^+

C OF_2 **D** BCl_3

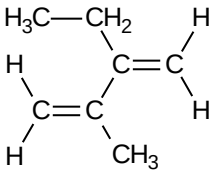
20. Which one of the following is **not** an isomer of the molecule shown below?



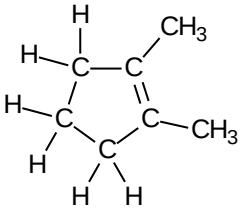
A



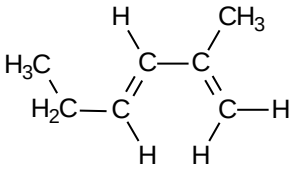
B



C



D



The Periodic Table of the Elements

Group I	Group II											Group III	Group IV	Group V	Group VI	Group VII	Group 0
							1 H hydrogen 1										4 He helium 2
7 Li lithium 3	9 Be beryllium 4											11 B boron 5	12 C carbon 6	14 N nitrogen 7	16 O oxygen 8	19 F fluorine 9	20 Ne neon 10
23 Na sodium 11	24 Mg magnesium 12											27 Al aluminium 13	28 Si silicon 14	31 P phosphorus 15	32 S sulfur 16	35.5 Cl chlorine 17	40 Ar argon 18
39 K potassium 19	40 Ca calcium 20	45 Sc scandium 21	48 Ti titanium 22	51 V vanadium 23	52 Cr chromium 24	55 Mn manganese 25	56 Fe iron 26	59 Co cobalt 27	59 Ni nickel 28	64 Cu copper 29	65 Zn zinc 30	70 Ga gallium 31	73 Ge germanium 32	75 As arsenic 33	79 Se selenium 34	80 Br bromine 35	84 Kr krypton 36
85 Rb rubidium 37	88 Sr strontium 38	89 Y yttrium 39	91 Zr zirconium 40	93 Nb niobium 41	96 Mo molybdenum 42	– Tc technetium 43	101 Ru ruthenium 44	103 Rh rhodium 45	106 Pd palladium 46	108 Ag silver 47	112 Cd cadmium 48	115 In indium 49	119 Sn tin 50	122 Sb antimony 51	128 Te tellurium 52	127 I iodine 53	131 Xe xenon 54
133 Cs caesium 55	137 Ba barium 56	139 La lanthanum 57 *	178 Hf hafnium 72	181 Ta tantalum 73	184 W tungsten 74	186 Re rhenium 75	190 Os osmium 76	192 Ir iridium 77	195 Pt platinum 78	197 Au gold 79	201 Hg mercury 80	204 Tl thallium 81	207 Pb lead 82	209 Bi bismuth 83	– Po polonium 84	– At astatine 85	– Rn radon 86
– Fr francium 87	– Ra radium 88	– Ac actinium 89 †															

*58-71 Lanthanoid series

†90-103 Actinoid series

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	– Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	162 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	– Pa protactinium 91	238 U uranium 92	– Np neptunium 93	– Pu plutonium 94	– Am americium 95	– Cm curium 96	– Bk berkelium 97	– Cf californium 98	– Es einsteinium 99	– Fm fermium 100	– Md mendelevium 101	– No nobelium 102	– Lr lawrencium 103

Key

a
X
b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

Answers

1. **A**
2. **B**
3. **B**
4. **B**
5. **D**
6. **C**
7. **B**
8. **C**
9. **D**

$$4CH_3NHNH_2(g) + 5N_2O_4(g) \rightarrow 4CO_2(g) + 12H_2O(g) + 9N_2(g)$$

10. **A**
11. **B**
12. **B**
13. **C**
14. **D**
15. **C**
16. **C**
17. **A**
18. **B**
19. **D**
20. **D**