## Merck State Science Day 2015

Chemistry

## Multiple Choice

Identify the choice that best completes the statement or answers the question and place your selection ON THE ANSWER PANEL, then "Confirm."

1. Atom $X$ has 6 valence electrons and atom $Y$ has 3 valence electrons. What is the simplest formula expected for the binary compound which contains these elements?
A) $X Y_{2}$
B) $\mathrm{XY}_{3}$
C) $X_{2} Y$
D) $X_{2} Y_{3}$
E) $\mathrm{X}_{3} \mathrm{Y}_{2}$
2. Which group of elements in the periodic table would be the easiest to reduce?
A) halogens
B) transuranic
C) alkali metals
D) transition metals
E) alkaline earth metals
3. Which ions will usually produce a precipitate with other ions in aqueous solution?
A) nitrate
B) sulfate
C) ammonium
D) sulfide
E) lithium
4. Burps are due to stress and swallowed gas. You love burping and decide to study it. You feel a discomfort when the pressure in your diaphragm is 2.05 atm (body temperature is $37^{\circ} \mathrm{C}$ ) and you burp into a balloon which inflates to 6.50 mL at 1.00 atm and $27^{\circ} \mathrm{C}$. The volume of the burp in your diaphragm is:
A) 0.230 mL
B) 0.305 mL
C) 3.26 mL
D) 3.28 mL
E) 4.35 mL
5. The anticancer drug, cis-platin, is used for treatment of solid tumors and is produced by reacting ammonia with potassium tetrachloroplatinate (KTCP) according to the balanced reaction below. The theoretical yield of cisplatin when 5.00 g ammonia and 50.0 g KTCP are used is:
(Formula masses: $\mathrm{K}_{2} \mathrm{PtCl}_{4}=415.1 \mathrm{~g} ; \mathrm{NH}_{3}=17.03 \mathrm{~g} ; \mathrm{Pt}\left(\mathrm{NH}_{3}\right)_{2} \mathrm{Cl}_{2}=300.1 \mathrm{~g}$ )

$$
\mathrm{K}_{2} \mathrm{PtCl}_{4}(s)+2 \mathrm{NH}_{3}(a q) \rightarrow \operatorname{Pt}\left(\mathrm{NH}_{3}\right)_{2} \mathrm{Cl}_{2}(s)+2 \mathrm{KCl}(a q)
$$

A) 4.08 g
B) 36.1 g
C) 44.1 g
D) 60.2 g
E) 87.0 g
6. Excess $\mathrm{AgNO}_{3}$ solution was added to a solution that contained 1.65 grams of a chloride salt, $\mathrm{MCl}_{3}$, of an unknown element M . The AgCl precipitate $(143.3 \mathrm{~g} / \mathrm{mol})$ after filtering and drying, weighed 2.49 grams. The element M is: $(\mathrm{Cl}=35.45 \mathrm{~g} / \mathrm{mol})$
A) Fe
B) Mo
C) Hf
D) Re
E) Ru
7. Species that in water can either accept or donate protons include

$$
\begin{array}{cl}
\text { I } & \mathrm{CH}_{4} \\
\text { II } & \mathrm{HCO}_{3}^{-} \\
\text {IIII } & \mathrm{HPO}_{4}{ }^{2-}
\end{array}
$$

A) I only
B) II only
C) III only
D) II and III only
E) I, II, and III
8. Which is NOT possible in thermodynamic reactions? Eliminated
A) $\Delta H$
B) $G<\theta$
C) $T \leq \theta$
D) $f<\theta$
E) $\pm \Delta G$
9. Which has a $+\Delta H$ ?
A) radioactive disintegration of Ra
B) discharge of a lead storage battery
C) forming hydrogen molecules from hydrogen atoms
D) combustion of coal
E) decomposition of water into hydrogen gas and oxygen gas
10. In which species does the central atom obey the octet rule?
A) $\mathrm{SF}_{4}$
B) $\mathrm{SiF}_{4}$
C) $\mathrm{XeF}_{4}$
D) $\mathrm{ClF}_{4}^{-}$
E) $\mathrm{ClF}_{5}{ }^{-}$
11. A student collects $250-\mathrm{mL}$ of an unknown gas in the laboratory at $25^{\circ} \mathrm{C}$ in a flask. The pressure of the gas was measured at 550 mmHg . If the gas sample has a mass of 0.118 g at this temperature, what is the formula for this unknown gas?
A) $\mathrm{N}_{2}$
B) $\mathrm{SO}_{3}$
C) Ne
D) $\mathrm{CH}_{4}$
E) PCl
12. How many different compounds have the formula, $\mathrm{C} 5 \mathrm{H}_{12}$ ?
A) 2
B) 3
C) 4
D) 5
E) an infinite number
13. Methane gas can be prepared by reacting water with solid aluminum carbide, according to the following unbalanced reaction:

$$
\mathrm{Al}_{4} \mathrm{C}_{3}(s)+12 \mathrm{H}_{2} \mathrm{O}(l) \rightarrow 4 \mathrm{Al}(\mathrm{OH})_{3}(s)+3 \mathrm{CH}_{4}(g)
$$

In the above reaction, 75.0 g of $\mathrm{Al}_{4} \mathrm{C}_{3}(90.03 \mathrm{~g} / \mathrm{mol})$ reacted with 100.0 g of $\mathrm{H}_{2} \mathrm{O}(18.02 \mathrm{~g} / \mathrm{mol})$, and a student obtains 20.0 g of $\mathrm{CH}_{4}(16.04 \mathrm{~g} / \mathrm{mol})$. What is the student's percent yield?
A) $39.8 \%$
B) $50.0 \%$
C) $79.7 \%$
D) $90.0 \%$
E) $100 \%$
14. Choose a name-formula pair that does NOT correctly match
A) sodium chlorite / NaClO
B) nickel(II) carbonate $/ \mathrm{NiCO}_{3}$
C) silver nitrate $/ \mathrm{AgNO}_{3}$
D) copper(II) sulfate pentahydrate $/ \mathrm{CuSO}_{4} \cdot 5 \mathrm{H}_{2} \mathrm{O}$
E) gold (II) nitrite $/ \mathrm{Au}\left(\mathrm{NO}_{2}\right)_{2}$
15. In gas phase reactions, the equilibrium constant is normally expressed as partial pressures of the reactants and products. If $[\mathrm{M}]$ represents the molar concentration, and other symbols of the ideal gas equation are used, which relationship is correct?
A)

$$
[\mathrm{M}]=\frac{R T}{P}
$$

B) $[\mathrm{M}]=\frac{R T}{V}$
C) $[\mathrm{M}]=\frac{p}{R T}$
D) $[\mathrm{M}]=\frac{P V}{R T}$
E) $[\mathrm{M}]=\frac{R T}{P V}$
16. Using the set of reactions and their equilibrium constants in the table, the $K$ for the reaction below is :

$$
\mathrm{CO}_{2}(\mathrm{~g}) \leftrightarrow \mathrm{C}(\mathrm{~s})+\mathrm{O}_{2}(\mathrm{~g})
$$

| $\mathrm{H}_{2}(\mathrm{~g})+1 / 2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{H}_{2} \mathrm{O}(\mathrm{l})$ | $K=4.44$ |
| :--- | :--- |
| $\mathrm{CH}_{4}(\mathrm{~g})+2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{CO}_{2}(\mathrm{~g})+2 \mathrm{H}_{2} \mathrm{O}(\mathrm{l})$ | $K=4.04$ |
| $\mathrm{C}(\mathrm{s})+2 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow \mathrm{CH}_{4}(\mathrm{~g})$ | $K=2.12$ |

A) 0.118
В) 0.433
C) 1.72
D) 2.30
E) 10.3
17. Raw milk sours in 4 hours at $27^{\circ} \mathrm{C}$ and 72 hours at $7^{\circ} \mathrm{C}$. What is the activation energy for this reaction? ( $R=8.314 \mathrm{~J} / \mathrm{mol} \cdot \mathrm{K}$ )
A) 0.227 kJ
B) 43.8 kJ
C) 101 kJ
D) 108 kJ
E) 149 kJ
18. In the following equilibrium the initial concentrations were $0.060 \mathrm{M} \mathrm{SO}_{2}$ and $0.050 \mathrm{M} \mathrm{O}_{2}$. After equilibrium was reached, the concentration of $\mathrm{SO}_{3}$ was 0.040 M . What is $\mathrm{K}_{\mathrm{c}}$ for this reaction?

$$
2 \mathrm{SO}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \leftrightarrow 2 \mathrm{SO}_{3}(\mathrm{~g})
$$

A) 0.0075
В) 0.11
C) 8.9
D) 67
E) 133
19. A possible mechanism for the reaction: $2 \mathrm{~A}+\mathrm{B} \rightarrow \mathrm{C}+\mathrm{D}$, is:
(i)

$$
\mathrm{A}+\mathrm{A} \rightarrow \mathrm{~A}_{2} \quad \text { fast, equilibrium }
$$

(ii)
(iii)

$$
\mathrm{A}_{2}+\mathrm{A} \rightarrow \mathrm{~A}_{3} \text { slow }
$$

$$
\mathrm{A}_{3}+\mathrm{B} \rightarrow \mathrm{~A}+\mathrm{C}+\mathrm{D} \text { fast }
$$

According to the mechanism, the rate law will be:
A) $\mathrm{rate}=\mathrm{k}[\mathrm{A}]^{2}$
B) rate $=k[\mathrm{~A}][\mathrm{B}]$
C) rate $=k[A]^{2}[B]$
D) rate $=k[\mathrm{~A}]^{3}$
E) $\mathrm{rate}=\mathrm{k}[\mathrm{A}][\mathrm{B}][\mathrm{C}]$
20. Arrange these substances in order of increasing boiling point: $\mathrm{Xe}, \mathrm{H}_{2}, \mathrm{H}_{2} \mathrm{O}, \mathrm{LiCl}, \mathrm{H}_{2} \mathrm{~S}$
A) $\mathrm{Xe}<\mathrm{H}_{2}<\mathrm{H}_{2} \mathrm{O}<\mathrm{LiCl}<\mathrm{H}_{2} \mathrm{~S}$
B) $\mathrm{Xe}<\mathrm{H}_{2}<\mathrm{H}_{2} \mathrm{~S}<\mathrm{H}_{2} \mathrm{O}<\mathrm{LiCl}$
C) $\mathrm{H}_{2}<\mathrm{Xe}<\mathrm{H}_{2} \mathrm{~S}<\mathrm{H}_{2} \mathrm{O}<\mathrm{LiCl}$
D) $\mathrm{H}_{2}<\mathrm{Xe}<\mathrm{H}_{2} \mathrm{O}<\mathrm{H}_{2} \mathrm{~S}<\mathrm{LiCl}$
E) $\mathrm{H}_{2} \mathrm{O}<\mathrm{LiCl}<\mathrm{Xe}<\mathrm{H}_{2}<\mathrm{H}_{2} \mathrm{~S}$
21. Assuming no change in volume, what mass of solid sodium acetate that should be added to 2.00 L of a 0.250 M acetic acid solution to prepare a buffer with a pH of 4.100 ?

| acetic acid, $p K_{a}$ | 4.757 |
| :--- | :---: |
| acetic acid, $\mathrm{CH}_{3} \mathrm{COOH}$, molar mass | $60.05 \mathrm{~g} / \mathrm{mol}$ |
| sodium acetate, $\mathrm{CH}_{3} \mathrm{COONa}$, molar mass | $82.05 \mathrm{~g} / \mathrm{mol}$ |

A) 0.0551 g
B) 2.26 g
C) 4.52 g
D) 9.04 g
E) 27.0 g
22. The graph shows the atomic radii of the first row transition elements. The best explanation for explaining the trend in atomic radii is increasing

A) nuclear charge.
B) electronegativity.
C) shielding effect.
D) number of valence electrons.
E) atomic number
23. The graph shows the titration curve of a weak polyprotic acid listed below with a strong base. What is the acid?


|  | Acid | $\boldsymbol{p} \boldsymbol{K}_{\boldsymbol{1}}$ | $\boldsymbol{p} \boldsymbol{K}_{\mathbf{2}}$ |  |
| :--- | :--- | :---: | :--- | :--- |
| A) | oxalic | 1.23 | 4.19 |  |
| B) | phosphoric | 2.14 | 7.20 |  |
| C) | citric | 3.13 | 4.77 |  |
| D) | succinic |  | 4.21 | 5.63 |
| E) | carbonic | 6.37 | 10.20 |  |

24. A molten solution of $\mathrm{AlCl}_{3}$ is electrolyzed for 10.0 hours with a current of 0.50 amperes to produce aluminum at one electrode and chlorine gas at the other. The electrode efficiency is $60 \%$. How many liters of $\mathrm{Cl}_{2}$ at STP is produced? $(F=96500 . ; 1$ hour $=3600 \mathrm{sec})$
A) 0.696 L
B) 1.25 L
C) 2.09 L
D) 2.50 L
E) 4.18 L
25. The diagram shows part of the DNA double helix in which the bases thymine (on the left) and adenine (on the right) are linked. What is the name given to the linking bonds, represented by the dotted lines?

A) covalent bonds
B) hydrogen bonds
C) ionic bonds
D) molecular bonds
E) nuclear bonds
26. Consider the compounds P to T :

| P | Q | R | S | T |
| :---: | :---: | :---: | :---: | :---: |
|  | $\begin{aligned} & \mathrm{CH}_{3}-\mathrm{CH}_{2}- \\ & \mathrm{CH}_{2} \mathrm{OH} \end{aligned}$ |  | $\mathrm{CH}_{3} \mathrm{CH}_{3} \mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OH}$ | $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{3}$ |

Which sequence gives the descending order (highest to lowest) of boiling point?
A) S $>$ Q $>$ R $>$ P $>$ T
B) S $>$ Q $>$ T $>$ P $>$ R
C) S $>$ Q $>$ R $>$ T $>$ P
D) R $>$ T $>$ P $>$ Q $>$ S
E) R $>$ T $>$ P $>$ Q $>$ S

Questions ?? and ?? deal with the solubility of $\mathrm{Cr}(\mathrm{OH})_{3}$ and the table below.

| $\mathrm{Cr}(\mathrm{OH})_{3}(s) \rightarrow \mathrm{Cr}^{3+}(a q)+3 \mathrm{OH}^{-}(a q)$ | $K_{s p}=6.7 \times 10^{-31}$ |
| :---: | :--- |
| $\mathrm{Cr}^{3+}(a q)+4 \mathrm{OH}^{-}(a q) \rightarrow \mathrm{Cr}(\mathrm{OH})_{4}{ }^{-}(a q)$ | $K_{f}=8 \times 10^{29}$ |

27. The solubility $\mathrm{Cr}(\mathrm{OH})_{3}$ in pure water is:
A) $8.2 \times 10^{-16} \mathrm{M}$
B) $5.4 \times 10^{-11} \mathrm{M}$
C) $8.8 \times 10^{-11} \mathrm{M}$
D) $1.3 \times 10^{-8} \mathrm{M}$
E) $2.9 \times 10^{-8} \mathrm{M}$
28. The solubility of $\mathrm{Cr}(\mathrm{OH})_{3}$ in 0.50 M NaOH when the complex ion $\mathrm{Cr}(\mathrm{OH})_{4}{ }^{-}$is formed is:
A) 0.32 M
В) 0.59 M
C) 0.27 M
D) 0.18 M
E) $9.6 \times 10^{5} \mathrm{M}$
29. Using the bond energies in the table, what is the molar enthalpy of combustion, $\Delta H_{\text {comb }}$, of acetylene, $\mathrm{C}_{2} \mathrm{H}_{2}$ ?
$\mathrm{C}_{2} \mathrm{H}_{2}+5 / 2 \mathrm{O}_{2} \rightarrow 2 \mathrm{CO}_{2}+$

| $\mathrm{C}-\mathrm{H}$ | 410 kJ |
| :--- | :--- |
| $\mathrm{C}=\mathrm{O}$ | 800 kJ |
| $\mathrm{O}=\mathrm{O}$ | 494 kJ |
| $\mathrm{C} \equiv \mathrm{C}$ | 835 kJ |
| $\mathrm{H}-\mathrm{O}$ | 460 kJ |

A) -6330 kJ
B) -1230 kJ
C) -370 kJ
D) -5 kJ
E) +2999 kJ
30. When ${ }_{84}^{214} P O$ decays, the emission consists consecutively of an alpha particle, then two beta particles, and finally another alpha particle. The resulting stable nucleus is:
A) ${ }_{23}^{206} \mathrm{Bi}$
B) ${ }_{23}^{210} \mathrm{Bi}$
C) ${ }_{82}^{206} \mathrm{~Pb}$
D) ${ }_{82}^{208} \mathrm{~Pb}$
E) ${ }_{82}^{208} \mathrm{Po}$
31. A student pipetted five $25.00-\mathrm{mL}$ samples of hydrochloric acid and transferred each sample to an Erlenmeyer flask, diluted each with distilled water, and added a few drops of phenolphthalein to each. Each sample was then titrated with a sodium hydroxide solution to the appearance of the first permanent faint pink color. The following results given in the table were obtained.

| Sample | Volume of added <br> NaOH Solution |
| :---: | :---: |
| 1 | 35.22 mL |
| 2 | 36.14 mL |
| 3 | 36.13 mL |
| 4 | 36.15 mL |
| 5 | 36.12 mL |

Which statement is the most probable explanation for the variation in the student's results?
A) The pipette was not rinsed with the HCl solution.
B) A different amount of water was added to the first sample
C) The burette was not rinsed with NaOH solution
D) he student added too little indicator to the first sample.T
E) The flask was not cleaned properly.
32. The equilibrium constant for the reaction $\mathrm{A}+2 \mathrm{~B} \rightarrow \mathrm{C}+\frac{5}{2} \mathrm{D}$ has a value of 4.0 . What is the value of the equilibrium constant for the reaction $2 \mathrm{C}+5 \mathrm{D} \rightarrow 2 \mathrm{~A}+4 \mathrm{~B}$ at the same temperature?
A) 0.063
В) 2.0
C) 4.0
D) 8.0
E) 160
33. For the transformation of grey tin into white tin, delta H is $2.09 \mathrm{~kJ} / \mathrm{mol}$ and delta S is $7.31 \mathrm{~J} / \mathrm{mol} \cdot \mathrm{K}$. At what temperature $(\mathrm{K})$ are the two forms of tin in equilibrium at 1 atm pressure?
A) 130
B) 273
C) 286
D) 304
E) 695
34. Consider the reaction:

$$
\begin{gathered}
2 \mathrm{CHCl}_{3}(\mathrm{l})+\mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{COCl}_{2}(\mathrm{~g})+2 \mathrm{HCl}(\mathrm{~g}) \\
\text { delta } \mathrm{H} \text { rxn }=-366 \mathrm{~kJ} \\
\text { delta } \mathrm{S}=+340 \mathrm{~J} / \mathrm{K}
\end{gathered}
$$

Is the formation of the poisonous gas phosgene, $\mathrm{COCl}_{2}$ spontaneous at $25^{\circ} \mathrm{C}$ ? ( $R=8.31 \mathrm{~J} / \mathrm{mol} \cdot \mathrm{K}$ )
A) Yes. The reaction is spontaneous.
B) The reaction does not occur but would with an increase in temperature.
C) The reaction does not occur but would with an increase in pressure.
D) The reaction will never occur under any conditions.
E) No, the reaction is at equilibrium.
35. Calculate the $\mathrm{E}^{\circ}$ for this redox reaction $(\mathfrak{J}=96500 \mathrm{C} / \mathrm{mol})$
$2 \mathrm{KMnO}_{4}+3 \mathrm{~K}_{2} \mathrm{C}_{2} \mathrm{O}_{4}+4 \mathrm{H}_{2} \mathrm{O} \rightarrow 2 \mathrm{MnO}_{2}+6 \mathrm{CO}_{2}+8 \mathrm{KOH} \quad$ Delta $\mathrm{G}=-625.3 \mathrm{~kJ}$
A) 0.810 V
B) 1.08 V
C) 2.16 V
D) 3.24 V
E) 6.48 V
36. The table shows the mass ratios of 4 oxides of nitrogen

| Oxide | I | II | III | IV |
| :---: | :---: | :---: | :---: | :---: |
| grams N | 7 | 7 | 7 | 7 |
| grams O | 4 | 8 | 16 | 20 |

From left to right, the four oxides are:
A) $\mathrm{NO}, \mathrm{NO}_{2}, \mathrm{~N}_{2} \mathrm{O}, \mathrm{N}_{2} \mathrm{O}_{5}$
B) $\mathrm{NO}_{2}, \mathrm{NO}, \mathrm{N}_{2} \mathrm{O}, \mathrm{N}_{2} \mathrm{O}_{5}$
C) $\mathrm{N}_{2} \mathrm{O}, \mathrm{NO}, \mathrm{NO}_{2}, \mathrm{~N}_{2} \mathrm{O}_{5}$
D) $\mathrm{NO}, \mathrm{NO}_{2}, \mathrm{~N}_{2} \mathrm{O}, \mathrm{N}_{2} \mathrm{O}_{5}$
E) $\mathrm{NO}_{2}, \mathrm{~N}_{2} \mathrm{O}, \mathrm{NO}, \mathrm{N}_{2} \mathrm{O}_{5}$
37. Data from the complete combustion of a compound containing only carbon, hydrogen and oxygen allows for analysis. What assumption(s) must be made to do the analysis?
I. The quantity of carbon dioxide formed relates directly to the amount of carbon on the sample.
II. The quantity of water formed relates directly to the amount of hydrogen in the sample.
III. The quantity of water formed is limited by the amount of oxygen in the sample.
IV. The quantity of carbon dioxide formed is limited by the amount of air present.
A) I only
B) II only
C) I and II only
D) I, II, and III only
E) All of them
38. When neutralized with NaOH , which of these acids will produce a solution with the highest pH ?
A) $\mathrm{HIO} \quad\left(K_{a}=2.3 \times 10^{-11}\right)$
B) $\mathrm{HCN} \quad\left(K_{a}=4.9 \times 10^{-10}\right)$
C) $\mathrm{HBrO}\left(K_{a}=2.5 \times 10^{-9}\right)$
D) $\mathrm{CH}_{3} \mathrm{COOH} \quad\left(K_{a}=1.8 \times 10^{-5}\right)$
E) $\mathrm{HF} \quad\left(K_{a}=3.5 \times 10^{-4}\right)$
39. Given:

## $\mathrm{CH}_{2}=\mathrm{CHCH}=\mathrm{C}=\mathrm{CHCH}=\mathrm{CH}_{2}$

How many sigma and how many pi bonds are there?
A) 6 sigma and 4 pi
B) 8 sigma and 7 pi
C) 8 sigma and 4 pi
D) 11 sigma and 3 pi
E) 14 sigma and 4 pi
40. Given:

$$
2 \mathrm{~A}(\mathrm{~g})+\mathrm{B}(\mathrm{~g}) \rightarrow 2 \mathrm{C}(\mathrm{~g}) K_{c}=10.0
$$

For which set of concentrations will the reaction proceed to the right?
[A], $M \quad[\mathrm{~B}], M \quad[\mathrm{C}], M$
А) $2.0 \quad 2.0 \quad 1.0$
В) $0.20 \quad 0.20 \quad 1.0$
C) $2.0 \quad 0.20 \quad 5.0$
D) $0.10 \quad 0.10 \quad 1.0$
E) $2.0 \quad 0.10 \quad 10.0$
41. Given at a certain temperature:

$$
\mathrm{CaO}(\mathrm{~s})+\mathrm{CO}_{2}(\mathrm{~g}) \leftrightarrow \mathrm{CaO}_{3}(\mathrm{~g}) \quad K_{p}=0.75 \mathrm{~atm}^{-1}
$$

What is the partial pressure of $\mathrm{CO}_{2}$ at equilibrium?
A) 0.13 atm
B) 0.38 atm
C) 0.75 atm
D) 1.5 atm
E) more information needed
42. The name of the compound whose overall formula is $\mathrm{Co}\left(\mathrm{NH}_{3}\right)_{6} \mathrm{Cl}_{3}$ and has a piece of its structure shown is:

A) tetraamminechlorocobalt(III) chloride
B) cis-tetraamminedichlorocobalt(III) chloride
C) trans-tetraamminedichlorocobalt(III) chloride
D) hexaamminecobalt(III) chloride
E) pentaamminechlorocobalt(III) chloride
43. A mass spectrometer fractures a molecule into pieces and separates the pieces by their individual masses. A mass spectrum is the record of the quantity of pieces of a particular mass and peak heights are proportional to the number of ions of each mass. The highest mass is the "parent" ion. The graph is a simplified mass spectrum of a compound that contains only $\mathrm{C}, \mathrm{H}$, and O . Use $\mathrm{C}=12, \mathrm{H}=1, \mathrm{O}=16$.

What molecule would show this mass spectrum?

A) $\mathrm{CHOCH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{3}$
B) $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{COCH}_{2} \mathrm{CH}_{3}$
C) $\mathrm{CH}_{3} \mathrm{COCH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{3}$
D) $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CHO}$
E) $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{OH}$
44. A $1^{\text {st }}$ order reaction has $\mathrm{t}_{1 / 2}=85 \mathrm{~min}$. What is its rate constant?
A) $0.0011 \mathrm{~min}^{-1}$
B) $0.0041 \mathrm{~min}^{-1}$
C) $0.082 \mathrm{~min}^{-1}$
D) $58.9 \mathrm{~min}^{-1}$
E) $122.7 \mathrm{~min}^{-1}$
45. An aliquot of $1.0 \mathrm{M} \mathrm{HCl}(a q)$ is added to 3 flasks each containing one of these slightly soluble salts.
I. $\mathrm{PbCl}_{2}$
II. $\mathrm{CuCO}_{3}$
III. $\mathrm{Ca}_{3}\left(\mathrm{PO}_{4}\right)_{2}$

Which will show an increase in solubility?
A) I only
B) II only
C) III only
D) I and II only
E) II and III only
46. A large glass cylinder is inverted over a lit wax $\left(\mathrm{C}_{25} \mathrm{H}_{52}\right)$ candle in a deep Petri dish filled halfway with water. When the candle goes out, the water rises into the cylinder.


All of these explain the phenomenon EXCEPT:
A) the $\mathrm{H}_{2} \mathrm{O}(g)$ cools into $\mathrm{H}_{2} \mathrm{O}(l)$
B) the loss of $\mathrm{O}_{2}(\mathrm{~g})$ in the air is replaced by the water
C) the $\mathrm{CO}_{2}(\mathrm{~g})$ produced exerts less pressure than the $\mathrm{O}_{2}$ used
D) the air cools, so it's volume decreases, so the water takes its place.
E) all explain this phenomenon.
47. In which molecule is the F-X-F angle the smallest?
A) $\mathrm{NF}_{3}$
B) $\mathrm{BF}_{3}$
C) $\mathrm{CF}_{4}$
D) $\mathrm{BrF}_{3}$
E) they are all equal
48. A 50.0 mL sample of 0.20 MCH 3 COOH , acetic or ethanoic acid, is titrated with 0.10 M NaOH . Determine the pH of the solution after the addition of 35.0 mL of NaOH . The $K_{a}$ of CH 3 COOH is $1.75 \times 10^{-5}$.
A) 1.11
В) 4.40
C) 4.75
D) 5.01
E) 7.00

Questions ?? and ?? deal with the following reaction:

$$
4 \mathrm{HBr}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \leftrightarrow 2 \mathrm{Br}_{2}(\mathrm{~g})+2 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g}) \quad K_{c}=88.5 \text { at } 500^{\circ} \mathrm{C}
$$

49. If $0.030 \mathrm{~mol} \mathrm{HBr}, 0.020 \mathrm{~mol} \mathrm{O}_{2}, 0.085 \mathrm{~mol} \mathrm{Br} 2$, and $0.090 \mathrm{~mol} \mathrm{H} \mathrm{H}_{2} \mathrm{O}$ are mixed in a 1 -liter container at $500^{\circ} \mathrm{C}$, how will the reaction proceed?
A) to produce more reactants
B) to produce more products
C) already at equilibrium
D) moves in both directions
E) not enough information
50. The value of $K_{p}$ for the above reaction is
А) 13.9
В) 21.6
C) 167
D) 885
E) $5.62 \times 10^{4}$
51. What happens when pure water freezes?
A) Heat is released and the temperature decreases.
B) Heat is absorbed and the temperature increases.
C) Heat is released and the temperature remains the same.
D) Heat is absorbed and the temperature remains the same.
E) Heat is neither released nor absorbed and the temperature remains the same.
52. White phosphorous is a molecular solid made of $\mathrm{P}_{4}$ tetrahedrons. Each P atom uses three $3 p$ orbitals to form the bonds. What properties would you expect for this material?
A) $60^{\circ} \mathrm{P}-\mathrm{P}$ bond angles, low melting point, soluble in non-polar solvents
B) $60^{\circ} \mathrm{P}-\mathrm{P}$ bond angles, low melting point, soluble in polar solvents
C) $60^{\circ} \mathrm{P}-\mathrm{P}$ bond angles, high melting point, soluble in non-polar solvents
D) $90^{\circ} \mathrm{P}-\mathrm{P}$ bond angles, low melting point, soluble in non-polar solvents
E) $109.5^{\circ}$ P-P bond angles, low melting point, soluble in non-polar solvents
53. Allene is a hydrocarbon molecule with a formula of $\mathrm{C}_{3} \mathrm{H}_{4}$. What type of hybrid orbitals and geometry does the central carbon atom have?
A) $s p^{3}$ and linear
B) $s p^{3}$ and bent (angular)
C) $s p^{2}$ and linea
D) $s p^{2}$ and bent (angular)
E) $s p$ and linear

## Matching

Questions \#??-??
A) Distillation
B) Paper chromatography
C) Filtration
D) Electrolysis
E) Re-crystallization
54. Method used for separating that doesn't depend on boiling point differences.
55. Method for separating liquid from solid without heating mixture.
56. Method of separation depends on relative retention of components of a mixture on a stationary phase.
57. Method for separation to purify soluble solids. ???? ANS

Questions ??-?? Given these aqueous solutions:
A) $0.1 \mathrm{M} \mathrm{NH}_{4} \mathrm{Cl}$
B) $0.1 \mathrm{M} \mathrm{Na}_{3} \mathrm{PO}_{4}$
C) $0.1 \mathrm{M} \mathrm{CuCl}{ }_{2}$
D) $0.1 \mathrm{M} \mathrm{HNO}_{3}$
E) $0.1 M \mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OH}$
58. Which solution has a $\mathrm{pH}=7$
59. Which solution will cause effervescence when mixed with $\mathrm{NaHCO}_{3}$ ?
60. Which solution will form a weakly basic solution with equal moles of HCl ?
61. Which solution when reacted with NaOH will form a water soluble gas?
62. Which solution is basic?

## Merck State Science Day 2015

## Chemistry

## Answer Section

## MULTIPLE CHOICE

1. E
2. A
3. D
4. D
a) did not K and inverted $\left(2.05^{*} 27\right) /(6.50 * 37)=\mathrm{X}$
b) used $(2.05 \mathrm{~atm} * 300 \mathrm{~K}) /(6.50 \mathrm{~mL} * 310 \mathrm{~K})=\mathrm{X}$
c) math error: $(2.05 * 310 * 1) /(6.50 * 300)=X$
d) correct $\left(6.50 \mathrm{~mL}^{*} 310 \mathrm{~K}^{*} 1 \mathrm{~atm}\right) /(2.05 \mathrm{~atm} * 300 \mathrm{~K})=X$
e) did not use Kelvin $(6.50 * 37 * 1) /\left(2.05^{*} 27\right)=X$
5. B
$50 \mathrm{~g} / 415.1=0.120 \mathrm{~mol} 5 \mathrm{~g} / 17 \mathrm{~g}=0.29 \mathrm{~mol}$ only $0.240 \mathrm{~mol} \mathrm{NH}_{3}$ needed for KTCP to react completely
a) used KTCP and found mass of $\mathrm{NH}_{3}$ used
b) correct: KTCP is the limiter: 0.120 mol KTCP yields 0.120 mol cis-platin* $330.1 \mathrm{~g} / \mathrm{mol}=36.1 \mathrm{~g}$
c) used $\mathrm{NH}_{3}$ as the limiter
d) used $\mathrm{NH}_{3}$ and found mass of KTCP needed
e) used $\mathrm{NH}_{3}$ but then forgot to divide by 2 .
6. C
7. D
8. D
9. E
10. B
11. D

$$
\text { PV=nRT, } \mathrm{n}=(0.0821)(25+273) /((550 / 760) * 0.25)=0.0074 \mathrm{~mol} ; 0.118 \mathrm{~g} / 0.0074 \mathrm{~mol}=15.96 \mathrm{~g} / \mathrm{mol}
$$

12. A
13. D

100 g water yields 22.2 g of methane, 75 g aluminum carbide could yield 40 g of methane

## A)

14. A
15. C
16. C
17. C
18. E
19. D
20. D
21. C
22. A
23. B
24. A
$36000 \mathrm{sec} \times 0.5 \mathrm{amp}=18000$ coul; 18000 coul/96500/6 e- x 22.4 L mol $=$
25. B
26. C
27. D
$K_{s p}=6.7 \times 10^{-31}=\mathrm{X} \cdot(3 \mathrm{x})^{3}$
28. C
29. B
$\Delta \mathrm{H}=$ bond energy of products - bond energy of reactants $=\left(2 * 800 * 2+2^{*} 460\right)-\left(835+2^{*} 410+2.5 * 494\right)=1230$
30. C
31. A
32. A
33. C
34. B
35. $B$
delta $\mathrm{G}=-\mathrm{nFE} E^{\circ}$
36. C
c) correct: the mass ratio of nitrogen to oxygen in each is:
$\mathrm{N}_{2} \mathrm{O}, 28: 16 \quad \mathrm{NO}, 14: 16 \quad \mathrm{NO}_{2}, 14: 32 \quad \mathrm{~N}_{2} \mathrm{O}_{5}, 28: 80$
37. C

C is correct: amount of $\mathrm{CO}_{2}$ is determined by amount of C and amount of $\mathrm{H}_{2} \mathrm{O}$ is determined by the amount of H
38. A

The weakest acid has the strongest conjugate base $\left(\mathrm{K}_{\mathrm{w}}=\mathrm{K}_{\mathrm{a}} \times \mathrm{K}_{\mathrm{b}}\right)$. At the equivalence point all that is left is the weak base.
39. E
e is correct: there are $8 \mathrm{C}-\mathrm{H}$ and $6 \mathrm{C}-\mathrm{C}$ sigma bonds, and $4 \mathrm{C}-\mathrm{C}$ multiple pi bonds
40. A
ans: $Q=[C]^{2} /[A]^{2}[B]$
a) correct $(1)^{2} /(2)^{2}(2)=0.13 \mathrm{~K}_{\mathrm{c}}>\mathrm{Q}$ therefore reaction proceeds to right
b) $(1)^{2} /(0.2)^{2}(0.2)=125 \mathrm{~K}_{\mathrm{c}}<\mathrm{Q}$
c) $(5)^{2} /(2)^{2}(0.2)=31 \mathrm{~K}_{\mathrm{c}}<\mathrm{Q}$
d) $(0.1)^{2} /(0 .)^{2}(0.1)=10 \mathrm{~K}_{\mathrm{c}}=\mathrm{Q}$
e) $(10)^{2} /(2.0)^{2}(10)=25,000 \mathrm{~K}_{\mathrm{c}}<\mathrm{Q}$
41. A
ans: a correct; $\mathrm{K}_{\mathrm{p}}=1 / P_{\mathrm{CO} 2} 1 / 0.75=0.13$
b) $0.75 / 2=0.38$
c) $\mathrm{K}_{\mathrm{p}}=\mathrm{P}_{\mathrm{CO} 2}$
d) at equilibrium so $\mathrm{P}_{\mathrm{CO2}}$ must equal 1
e) thinks you need solid amounts
42. $B$
43. $B$
44. C
45. E
ans: $\mathbf{E}$ the anions of weak acids are basic and will increase in solubility in acids
46. $B$
a) the $\mathrm{CO} 2(\mathrm{~g})$ produced dissolves in the water in the beaker, thus the total volume of gas in the beaker is reduced, so the water takes its place
ans: $\mathbf{b} \mathrm{C}_{25} \mathrm{H}_{52}(\mathrm{~s})+38 \mathrm{O}_{2}(g) \rightarrow 25 \mathrm{CO}_{2}(g)+26 \mathrm{H}_{2} \mathrm{O}(g)$
as shown by the equation for every $38 \mathrm{O}_{2}(g)$ reacted a total of 51 moles of gas is produced so the pressure is increased until the $\mathrm{CO}_{2}(\mathrm{~g})$ dissolves in the water and the $\mathrm{H}_{2} \mathrm{O}(\mathrm{g})$ condenses
47. D
ans: $\mathbf{d ~} \mathrm{BrF}_{3}$ is T -shaped so $90^{\circ}, \mathrm{NF}_{3}$ is trigonal pyramidal so $107^{\circ}, \mathrm{CF}_{4}$ is tetrahedral so $109.5^{\circ}$
48. $B$
49. A
50. A
51. C
52. A
53. E

## MATCHING

54. E
55. C
56. B
57. A
58. E
59. D
60. B
61. A
62. $B$
