Honour Chemistry: Seniors Practice Final Exam (Semester 2)

Part A*: *Multiple Choice and Numerical Response

1. Which of the following equations is associated with the largest energy change per mole of fluorine?

A. $F_{2\,(g)} \rightarrow F_{2\,(l)}$
B. ${}^{19}_{9}F + {}^{4}_{2}He \rightarrow {}^{1}_{0}n + {}^{22}_{11}Na$
C. $2\,F_{2\,(g)} + 2\,H_2O_{\,(l)} \rightarrow O_{2\,(g)} + 4\,HF_{\,(aq)}$
D. $CH_{4\,(g)} + 2\,Cl_{2\,(g)} + 2\,F_{2\,(g)} \rightarrow CCl_2F_{2\,(g)} + 2\,HCl_{\,(g)} + 2\,HF_{\,(g)}$

2. Which of the following molecular properties is a main component of the chemical potential energy of matter?

A. Vibrational motion
B. Intramolecular bonding
C. Movement from place to place
D. Rotation about the molecules' centre of mass

3. When one mole of sodium bicarbonate is formed from its elements, 947.7 kJ of heat energy is released into the surroundings. This enthalpy change can be represented as

A. $Na_{\,(s)} + \frac{1}{2}\,H_{2\,(g)} + C_{\,(s)} + \frac{3}{2}\,O_{2\,(g)} \rightarrow NaHCO_{3\,(s)} + 947.7\text{ kJ}$
B. $Na_{\,(s)} + \frac{1}{2}\,H_{2\,(g)} + C_{\,(s)} + \frac{3}{2}\,O_{2\,(g)} + 947.7\text{ kJ} \rightarrow NaHCO_{3\,(s)}$
C. $Na^{+}_{\,(aq)} + HCO_3^{-}{}_{\,(aq)} \rightarrow NaHCO_{3\,(s)} + 947.7\text{ kJ}$
D. $Na^{+}_{\,(aq)} + HCO_3^{-}{}_{\,(aq)} + 947.7\text{ kJ} \rightarrow NaHCO_{3\,(s)}$

Use the following information to answer the next question.

Cold packs are commonly used by athletes to reduce swelling caused by injury. The packs consist of two plastic pouches: an inner pouch that contains a chemical and an outer pouch that contains water. When the inner pouch is broken, the chemical and water mix, which causes the pack to feel cold.

Statements

1 Ice is considerably less expensive than are commercial cold packs.

2 Ammonium nitrate is commonly used in cold packs because its heat of solution is endothermic.

3 The disposal of cold packs poses a landfill concern.

4 Durability and flexibility are design requirement for the plastic outer pouch.

Numerical Response

1. The statements above that reflect an ecological, scientific, economic and technological perspective are, respectively, ______, ______, _______, and ______.

Numerical Response

2. To the nearest tenth, the energy released when 1.00 mol of $AgI_{(s)}$ is formed from its elements is _____ kJ.

Use the following information to answer the next two questions.

Glucose is a biological fuel used by cells to satisfy the energy needs of plants and animals. The overall reaction for the metabolism of glucose is represented by the **unbalanced** equation

$$\_\_\_\_ \ C_6H_{12}O_{6\,(s)} + \_\_\_\_ \ O_{2\,(g)} \rightarrow \_\_\_\_ \ CO_{2\,(g)} + \_\_\_\_ \ H_2O_{(l)}$$

4. The balanced equation and the enthalpy change for the cellular respiration of glucose can be represented as

A. $C_6H_{12}O_{6\,(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} + H_2O_{(l)} + 593.8$ kJ
B. $C_6H_{12}O_{6\,(s)} + 6\ O_{2\,(g)} + 2802.7$ kJ $\rightarrow 6\ CO_{2\,(g)} + 6\ H_2O_{(l)}$
C. $C_6H_{12}O_{6\,(s)} + 6\ O_{2\,(g)} \rightarrow 6\ CO_{2\,(g)} + 6\ H_2O_{(l)} + 2802.7$ kJ
D. $C_6H_{12}O_{6\,(s)} + 6\ O_{2\,(g)} \rightarrow 6\ CO_{2\,(g)} + 6\ H_2O_{(l)} + 2538.7$ kJ

5. If solid glucose is completely burned in the flame of a Bunsen burner, the enthalpy change is

A. greater than it is during cellular respiration because the production of $H_2O_{(g)}$ releases more energy than does the production of $H_2O_{(l)}$
B. less than it is during cellular respiration because the production of $H_2O_{(g)}$ releases less energy than does the production of $H_2O_{(l)}$
C. the same as it is in the body because the enthalpy change is independent of the state of the products
D. the same as it is in cellular respiration because they are identical processes

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6. When 1.65 g of ethanal ($CH_3CHO_{(l)}$) is burned in a calorimeter to produce $H_2O_{(l)}$ and $CO_{2\,(g)}$, 44.7 kJ of heat energy is produced. According to this experimental data, the molar enthalpy of combustion of ethanal is

A. $+1.52 \times 10^3$ kJ/mol **B.** –76.6 kJ/mol **C.** –165 kJ/mol **D.** -1.19×10^3 kJ/mol

Numerical Response

3. To the nearest hundredth, A student heated a 120.0 g sample of $H_2O_{(l)}$ from 21.0°C to 32.5°C by adding 5.93 kJ of energy. The student then used this data to calculate the specific heat capacity of water and compared it with the standard value. The experimental percentage difference was __________ %.

Use the following information to answer the next question.

$$2\ C_2H_{2\,(g)} + 5\ O_{2\,(g)} \rightarrow 4\ CO_{2\,(g)} + 2\ H_2O_{(g)} \qquad \Delta H = -2511.0 \text{ kJ}$$

Numerical Response

4. To the nearest hundredth, the amount of energy released by the combustion of 100 g of $C_2H_{2\,(g)}$ is ________ MJ.

Use the following information to answer the next question.

Many insects and small animals have unique defence systems. Bombardier beetles fight off predators with a hot chemical spray. This spray consists of solutions of hydroquinone ($C_6H_4(OH)_{2\,(aq)}$), hydrogen peroxide ($H_2O_{2\,(aq)}$), and enzymes, which are secreted by the beetles' glands.

Reaction Equation Related to Spray Formation

I	$2\ H_2O_{(l)} + O_{2\,(g)} \rightarrow 2\ H_2O_{2\,(aq)}$	$\Delta H = +189.2$ kJ
II	$H_2O_{(l)} \rightarrow H_{2\,(g)} + \frac{1}{2}\ O_{2\,(g)}$	$\Delta H = +285.8$ kJ
III	$C_6H_4(OH)_{2\,(aq)} \rightarrow C_6H_4O_{2\,(aq)} + H_{2\,(g)}$	$\Delta H = +177.0$ kJ

A chemical reaction that occurs in order to produce the hot chemical spray can be represented by the equation

$$\underset{\text{hydroquinone}}{C_6H_4(OH)_{2\,(aq)}} + H_2O_{2\,(aq)} \rightarrow \underset{\text{quinone}}{C_6H_4O_{2\,(aq)}} + 2\ H_2O_{(l)}$$

7. The heat of reaction for the production of this hot chemical spray is

A. –489.2 kJ **B.** –203.4 kJ **C.** –82.4 kJ **D.** +12.2 kJ

Use the following equations to answer the next question.

Energy Reaction Equations

I	$C_6H_{12}O_{6\,(aq)} + 6\ O_{2\,(g)} \rightarrow 6\ CO_{2\,(g)} + 6\ H_2O_{(l)}$ + energy
II	${}^1_1H + {}^3_1H \rightarrow {}^4_2He$ + energy
III	$6\ CO_{2\,(g)} + 6\ H_2O_{(l)}$ + energy $\rightarrow C_6H_{12}O_{6\,(aq)} + 6\ O_{2\,(g)}$

8. The energy reactions above involve the conversion of energy for metabolic (body) processes. The chronological order of these reactions is

A. I, III, and II **B.** III, II, and I **C.** II, III, and I **D.** II, I, and III

9. The total enthalpy change associated with the conversion of 1.00 Mg of water at 20.0°C into steam at 250.0°C could be calculated by using the formula

A. [1.00 Mg × 4.19 J/(g • °C) × 80.0°C] + [(1.00 Mg/18.02 g/mol) × 40.65 kJ/mol]
B. [1.00 Mg × 2.02 J/(g • °C) × 230.0°C] + [(1.00 Mg/18.02 g/mol) × 40.65 kJ/mol]
C. [1.00 Mg × 4.19 J/(g • °C) × 80.0°C] + [(1.00 Mg/18.02 g/mol) × 40.65 kJ/mol] + [1.00 Mg × 4.19 J/(g • °C) × 150.0°C]
D. [1.00 Mg × 4.19 J/(g • °C) × 80.0°C] + [(1.00 Mg/18.02 g/mol) × 40.65 kJ/mol] + [1.00 Mg × 2.02 J/(g • °C) × 150.0°C]

At the Acme Gas Plant in Texas, environmental and economic concerns have resulted in the development of an efficient process for the removal of sulfur from sour gas, which is a mixture of hydrocarbons and $H_2S_{(g)}$. In the first step of the process, one-third of the $H_2S_{(g)}$ reacts with $O_{2\,(g)}$ to produce $SO_{2\,(g)}$. In the second step of the process, the $SO_{2\,(g)}$ produced reacts with the remaining $H_2S_{(g)}$ to form elemental sulfur and water.

Step I	$2\,H_2S_{(g)} + 3\,O_{2\,(g)} \rightleftharpoons 2\,H_2O_{(g)} + 2\,SO_{2\,(g)}$
Step II	$2\,H_2S_{(g)} + SO_{2\,(g)} \rightleftharpoons 2\,H_2O_{(g)} + 3\,S_{(s)}$
Overall equation	$2\,H_2S_{(g)} + O_{2\,(g)} \rightleftharpoons 2\,H_2O_{(g)} + 2\,S_{(s)}$

To maximize the amount of sulfur removed from the sour gas, the gas plant engineers apply Le Châtelier's principle.

10. According to the overall equilibrium equation above, the amount of sulfur removed may be increased by

A. adding a catalyst
B. removing water vapour
C. increasing the volume of the system
D. increasing the temperature of the system

11. As $H_2S_{(g)}$ forms $S_{(s)}$, the oxidation number of sulfur

A. changes from 0 to –2 and sulfur is reduced
B. changes from –2 to 0 and sulfur is oxidized
C. decreases by 2 and hydrogen sulfide acts as the reducing agent
D. stays the same because the sulfur is neither oxidized nor reduced

Use the following information to answer the next question.

The sulfur produced in step II is initially produced in liquid form. As it cools, it is converted from a liquid state to a solid state as represented by the equation

$$S_{(l)} \rightarrow S_{(s)}$$

12. In terms of energy, this conversion is

A. endothermic, releases heat, and has a positive ΔH
B. exothermic, releases heat, and has a negative ΔH
C. exothermic, absorbs heat, and has a negative ΔH
D. endothermic, absorbs heat, and has a positive ΔH

Use the following information to answer the next question.

The burning of methane in a Bunsen burner to produce energy can be represented by the equation

$$CH_{4\,(g)} + 2\,O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2\,H_2O_{(g)}$$

13. A student determined that the reaction represented by the equation above is **not** at equilibrium because

A. the system is open
B. a catalyst is not present
C. the temperature is constant
D. both reactants and products are gases

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14. Which of the following chemical changes would have the greatest percentage of products at equilibrium?

A. $AgCl_{(s)} \rightleftharpoons Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$ $K_{eq} = 2.0 \times 10^{-10}$

B. $BaCO_{3\,(s)} \rightleftharpoons Ba^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)}$ $K_{eq} = 5.5 \times 10^{-10}$

C. $HOBr_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^{+}_{(aq)} + OBr^{-}_{(aq)}$ $K_{eq} = 2.0 \times 10^{-10}$

D. $NH_2OH_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_3OH^{+}_{(aq)} + OH^{-}_{(aq)}$ $K_{eq} = 1.1 \times 10^{-8}$

The production of paper can involved the reaction of the hydrated aluminum ion $Al(H_2O)_6^{3+}{}_{(aq)}$ with water.

$$Al(H_2O)_6^{3+}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons Al(OH)(H_2O)_5^{2+}{}_{(aq)} + H_3O^{+}_{(aq)} \qquad K_a = 1.4 \times 10^{-5}$$

15. The acid dissociation expression for this system is

A. $K_a = \dfrac{[Al(OH)(H_2O)_5^{2+}{}_{(aq)}]}{[Al(H_2O)_6^{3+}{}_{(aq)}]}$

B. $K_a = \dfrac{[Al(OH)(H_2O)_5^{2+}{}_{(aq)}][H_3O^{+}{}_{(aq)}]}{[Al(H_2O)_6^{3+}{}_{(aq)}][H_2O_{(l)}]}$

C. $K_a = \dfrac{[Al(OH)(H_2O)_5^{2+}{}_{(aq)}]}{[Al(H_2O)_6^{3+}{}_{(aq)}][H_2O_{(l)}]}$

D. $K_a = \dfrac{[Al(OH)(H_2O)_5^{2+}{}_{(aq)}][H_3O^{+}{}_{(aq)}]}{[Al(H_2O)_6^{3+}{}_{(aq)}]}$

*Use your recorded answer for **Multiple Choice 15** to answer **Multiple Choice 16****

16. The $[H_3O^{+}]$ in a 0.585 mol/L $Al(H_2O)_6^{3+}{}_{(aq)}$ solution is

A. 8.2×10^{-6} mol/L **B.** 2.4×10^{-5} mol/L **C.** 4.9×10^{-3} mol/L **D.** 2.9×10^{-3} mol/L

***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the following information to answer the next question.

Three Important Equilibria in Blood

$$\underset{\text{hemolglobin}}{HBb^{+}_{(aq)}} + O_{2\,(g)} \rightleftharpoons \underset{\text{oxyhemoglobin}}{HbO_{2\,(aq)}} + H^{+}_{(aq)}$$

$$H^{+}_{(aq)} + HCO_3^{-}{}_{(aq)} \rightleftharpoons H_2CO_{3\,(aq)}$$

$$H_2CO_{3\,(aq)} \rightleftharpoons CO_{2\,(g)} + H_2O_{(l)}$$

17. In blood, the $[H^{+}_{(aq)}]$ could be increased by decreasing the

A. $[CO_{2\,(g)}]$ **B.** $[O_{2\,(g)}]$ **C.** $[HCO_3^{-}{}_{(aq)}]$ **D.** $[H_2CO_{3\,(aq)}]$

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18. The electron configuration of a ground-state copper atom is

A. $[Ar]4s^24d^4$. **B.** $[Ar]4s^23d^9$. **C.** $[Ar]3d^9$. **D.** $[Ar]4s^13d^{10}$.

19. Which of these choices is the electron configuration of an *excited state* of an iron atom?

A. $[Ar]4s^2 3d^6$ **B.** $[Ar]3d^5$ **C.** $[Ar]4s^1 3d^7$ **D.** $[Ar]4s^1 3d^5$

20. Which of these pairs consists of *isoelectronic* species?

A. Zn^{2+} and Cu^{2+} **B.** Na^+ and K^+ **C.** Cl^- and S **D.** K^+ and Cl^-

21. The electron configuration of a cobalt (III) ion is

A. $[Ar]3d^5$. **B.** $[Ar]4s^1 3d^5$. **C.** $[Ar]4s^2 3d^4$. **D.** $[Ar]3d^6$.

22. Arrange these ions in order of increasing ionic radius: K^+, P^{3-}, S^{2-}, Cl^-.

	Increasing radius →
Row 1	$K^+ < Cl^- < S^{2-} < P^{3-}$
Row 2	$K^+ < P^{3-} < S^{2-} < Cl^-$
Row 3	$P^{3-} < S^{2-} < Cl^- < K^+$
Row 4	$Cl^- < S^{2-} < P^{3-} < K^+$

A. Row 1 **B.** Row 2 **C.** Row 3 **D.** Row 4

23. Which of these elements has the smallest ionization energy?

A. Li **B.** Na **C.** K **D.** Rb

24. Which of these elements has the greatest electron affinity (largest positive value)?

A. Al **B.** Si **C.** P **D.** S

25. The total number of bonding electrons in a molecule of formaldehyde (H_2CO) is

A. 3. **B.** 4. **C.** 6. **D.** 8.

26. Which molecule has a Lewis structure that does not obey the octet rule?

A. CS_2 **B.** NO_2 **C.** PH_3 **D.** CCl_4

27. Which of the following substances should have the highest boiling point?

A. CH_4 **B.** Cl_2 **C.** CH_3Cl **D.** Kr

28. Which two properties are more typical of molecular compounds than of ionic compounds?

I. They are gases or liquids at room temperature.
II. They have high melting points.
III. Solids do not conduct electricity, but liquids do.
IV. Atoms share electrons.

A. I and IV **B.** I and III **C.** II and III **D.** II and IV

29. Which one of the following substances should exhibit hydrogen bonding in the liquid state?

A. PH_3 **B.** H_2S **C.** CH_4 **D.** NH_3

30. A student was given data concerning the boiling points of hydrogen compounds in the fourth period of the periodic table.

Compound	Boiling Point (°C)
GeH_4	–89
AsH_3	–55
H_2Se	–42
HBr	–67

The best hypothesis the student could make to explain the drop in boiling points between H_2Se and HBr is that

A. the H_2Se intramolecular bonds are more polar than for HBr
B. hydrogen bonding occurs with H_2Se but not with HBr
C. fewer intermolecular bonds can form with HBr compared to H_2Se because of its shape
D. HBr has too many lone pairs of electrons to make strong intermolecular bonds

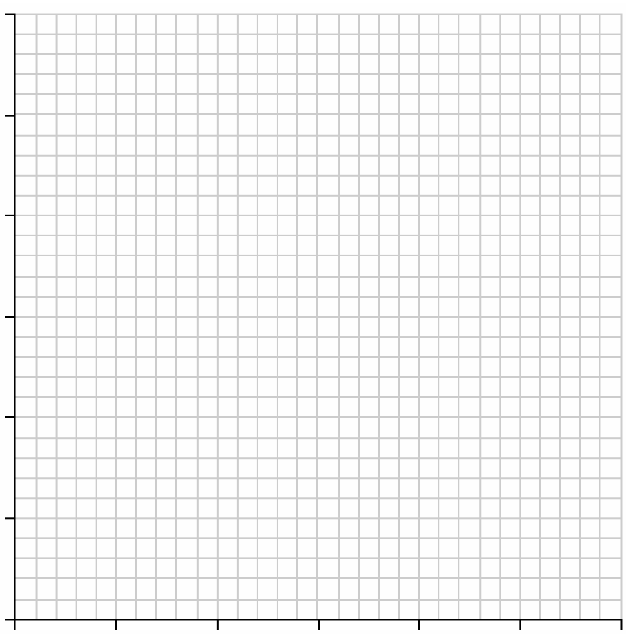
Part B: Written Response

Use the following information to answer the next question.

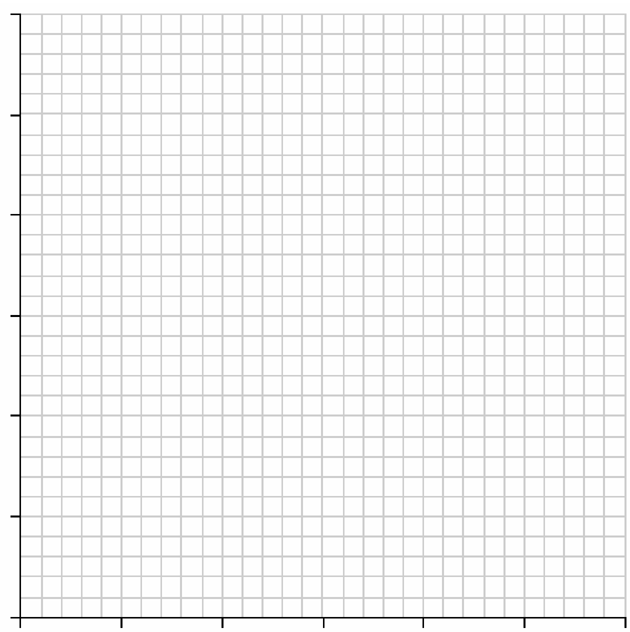
> Most arenas and curling rink have artificial ice. Many ice-making plants use ammonia as the refrigerant. The ammonia is circulated in pipes under the ice of the arena or curling rink. For this question, assume that the **only** changes to the ammonia are represented in the equilibrium.
>
> $$NH_{3\,(l)} \rightleftharpoons NH_{3\,(g)} \qquad \Delta H = +23.3 \text{ kJ}$$

1. a. On the axes provided, draw and label, as precisely as possible, the graphs that represent the energy changes that occur to the ammonia below the ice surface and to the water on the ice surface as the refrigeration system operates. Assume that the water applied to the ice surface is initially at 20.00°C.

Ammonia Change



Water Change



b. What mass of ammonia must undergo a phase change in order to change 1.00×10^7 g (10.0 kL) of water at 20.00°C to ice at 0.00°C?

Use the following information to answer the next question.

> The formation of a pollutant gas, nitrogen monoxide ($NO_{(g)}$), by the reaction of nitrogen with oxygen in a gasoline engine can be affected by changing the combustion temperature within the engine. The equilibrium constant for the production of one mole of $NO_{(g)}$ at 25°C is 1.0×10^{-17}

2. Explain how an increase in temperature could affect the concentration of the pollutant gas and the equilibrium constant.

Your response should also include

- relevant chemical equation(s) and values from the chemistry data booklet
- a description of two ways that car manufacturers could reduce the $NO_{(g)}$ emissions in new model vehicles

3. For the following compounds or ions, draw the Lewis dot diagram and predict its molecular geometry. Indicate any compound that has resonance structures.

a. PF_5 **b.** $SiCl_4$ **c.** NO_3^-

Answers

Multiple Choice

1.	B	**2.**	B	**3.**	A	**4.**	C	**5.**	B	**6.**	D	**7.**	B	**8.**	C	**9.**	D	**10.**	B	**11.**	B
12.	B	**13.**	A	**14.**	D	**15.**	D	**16.**	D†	**17.**	C	**18.**	D	**19.**	C	**20.**	D	**21.**	D	**22.**	C
23.	D	**24.**	D	**25.**	D	**26.**	B	**27.**	C	**28.**	A	**29.**	D	**30.**	C						

Linked Items:

† If MC15 is A or C, then MC16 is A

† If MC15 is B or D, then MC16 is D

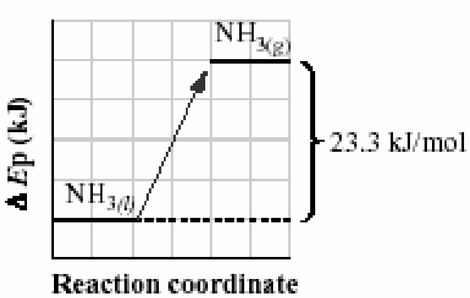
Numerical Response

1. 3214 **2.** 61.8 **3.** 2.56 or 2.63 **4.** 4.82

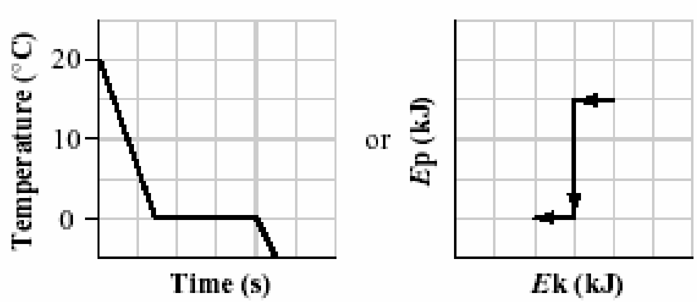
Written Response

1. a.

Ammonia



Water



b. Heat Gained (Ammonia) = Heat Lost (Water)

$$n_{\mathrm{NH_3}}\Delta H_{vap,\,\mathrm{NH_3}} = m_w C_w \Delta T_w + n_w \Delta H_{fus}$$

$$n_{\mathrm{NH_3}} = \frac{m_w C_w \Delta T_w + n_w \Delta H_{fus}}{\Delta H_{vap,\mathrm{NH_3}}} = \frac{\left(1.00\times10^4\ \cancel{\text{kg}}\right)\left(4.19\ \text{kJ}/\left(\cancel{\text{kg}\bullet{}^\circ\text{C}}\right)\right)\left(20.00\ \cancel{^\circ\text{C}}\right)+\left(\dfrac{1.00\times10^7\ \cancel{\text{g}}}{18.02\ \cancel{\text{g}}/\cancel{\text{mol}}}\right)\left(6.03\ \cancel{\text{kJ}}/\cancel{\text{mol}}\right)}{\left(23.3\ \cancel{\text{kJ}}/\text{mol}\right)}$$

$n_{\mathrm{NH_3}}$ = 179582.9145 mol

$m_{\mathrm{NH_3}} = nM$ = (179582.9145 mol)(17.04 g/mol) = 3,060,092.864 g

$\boldsymbol{m_{\mathrm{NH_3}}}$ **= 3.06 × 10^6 g or 3.06 × 10^3 kg or 3.06 Mg**

2. Chemical Equation

½ $N_{2\,(g)}$ + ½ $O_{2\,(g)}$ ⇌ $NO_{(g)}$ Δ*H* = +90.2 kJ *or* $N_{2\,(g)}$ + $O_{2\,(g)}$ ⇌ 2 $NO_{(g)}$ Δ*H* = +180.4 kJ

Explanations

The reaction is endothermic. Therefore, according to Le Châtelier's Principle, increasing the temperature should shift the equilibrium to the right that will cause an increase in [$NO_{(g)}$].

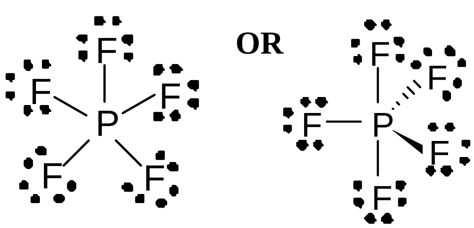
The K_{eq} value is temperature dependent. At a higher temperature, more $NO_{(g)}$ is produced therefore the *K* value would increase.

$$K_{eq} = \frac{\left[\mathrm{NO}_{(g)}\right]\uparrow}{\left[\mathrm{N}_{2(g)}\right]^{\frac{1}{2}}\downarrow\times\left[\mathrm{O}_{2(g)}\right]^{\frac{1}{2}}\downarrow} = 1.0\times10^{-17}\ \text{(increases)}$$

Ways to reduce $NO_{(g)}$ emissions

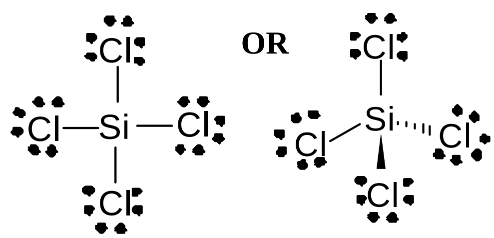
- Car manufacturers should try to decrease engine combustion temperatures.
- Install emission control devices. (Catalytic reduction of $NO_{(g)}$ emissions.)
- Install $N_{2\,(g)}$ absorbent before combustion takes place in the engine.
- More efficient fuel/car with an explanation.
- Use of hybrid/electric/solar cars.

3. a. PF_5



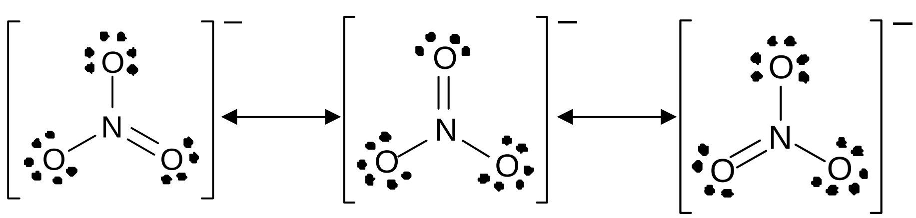
Trigonal bipyramid

b. $SiCl_4$



Tetrahedral

c. NO_3^-



Trigonal planar