Name _____

Chemistry Module Quiz for Science and Technology for NPTS

Spring 2017 Key

1. Write the term in the blank that corresponds to the following definitions. (1 point each)

   a. **Precursor** Any chemical reactant that takes part at any stage in the production by whatever method of a toxic chemical.

   b. **Choking agent** Compounds that disrupt the victim's ability to breathe. Chlorine and phosgene are examples.

   c. **Active site** A specific section of the protein structure of an enzyme in which the substrate fits and reacts.

   d. **1925 Geneva Protocol** Protocol on the Prohibition of the Use in War of Asphyxiating, Poisonous or Other Gases, and of Bacteriological Methods of Warfare

   e. **Toxin** A poisonous substance produced within living cells or organisms.

   f. **Hydrolysis** The reaction in which water, H_2O, divides into H, which combines with one part of a molecule, and OH, which combines with another part of the molecule, splitting the molecule into two parts.

2. Kim Jong-nam, the half-brother of North Korea's leader, died in Malaysia on 13 February 2017. Subramaniam Sathasivam, Malaysia's health minister, said he was exposed to the nerve agent VX, and he died in pain within 15-20 minutes. Let's evaluate the credibility of this claim. (Unless otherwise stated, 3 points each part)
   a. How quickly do nerve agents act? Does death within 15-20 minutes fit for VX?

Nerve agents act quickly and can be lethal in as little as 4-5 minutes. It takes a little longer for skin contact because it takes a bit of time to migrate through the top layer of skin. The timing seems to fit.

b. Kim Jong-nam was thought to be exposed to VX when someone rubbed it on his face. Can VX be lethal from skin exposure? Is it just as likely that the nerve agent was sarin?

Yes, VX can be absorbed by the skin. Sarin is not as dermally active, so it's less likely that the agent would have been sarin.

c. Subramaniam Sathasivam said that no antidote would have worked. Is this true? What are the two primary antidotes for nerve agents, such as VX. Do they both work quickly?

There are antidotes for VX, and if they had been administered very, very quickly it could have saved Kim Jong-nam's life. By the time he got medical attention, it was probably too late. Atropine is the fast acting antidote that lessens the symptoms, but it does not treat the cause. It provides time for the slower-acting 2-PAM to provide a more long-term fix.

d. Malaysian police said that the two attackers had been instructed to wash their hands immediately after the attack. Although reports say that one of the attackers vomited after the attack, they did not exhibit any other significant effects of VX exposure. One suggestion used to explain the lack effects on the attackers is that they transferred two nonlethal chemicals that form VX to Kim Jong-nam's face and not VX itself. These chemicals then reacted to form VX. Based on your knowledge of binary nerve agent weapons, does this seem like a credible suggestion?

In a binary VX weapon, two safer precursors (QL and sulfur) are mixed in flight, and they react to form VX. If these two precursors were mixed on Kim Jong-nam's face, VX could form there, making it deadly for him but safer for the attackers.

e. Some people have questioned whether VX was used and point to the fact that the emergency personnel had no ill effects. Does the VX evaporate fast enough to be dangerous to people close to Kim Jong-nam? If the emergency personnel wore gloves and disposed of the gloves properly, does it make sense that they would have no ill effects?

VX is not very volatile, so it's possible that a small amount left on Kim Jong-nam's face would not evaporate fast enough to cause harm to the attackers and the medical personnel.

f. It has been suggested that the North Korean government was behind the attack. What are the ways someone can get chemical weapons? How hard would it be to obtain VX? How difficult is it to make VX? Does it seem like a small terrorist group could obtain VX? How difficult is it to obtain the precursors necessary to make VX?

Chemical weapons can be produced, stolen (either from a chemical facility or in transit), or discovered in a cache. It's very difficult to get VX. There only a handful of countries who have stockpiled it. It is difficult to make because it requires sophisticated equipment, chemical expertise, and precursors that are regulated. It's unlikely that a terrorist group could make VX. It's more likely that it was made by the North Koreans.

g. Has North Korea signed and ratified the Chemical Weapons Convention? Are they thought to have chemical weapons?

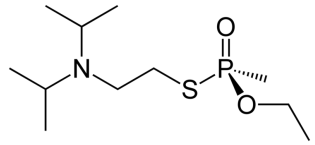
No, they have neither signed nor ratified the CWC. They certainly have the capability of making chemical weapons, and it is thought that they have the third largest stockpile of chemical weapons, after the U.S. and Russia.

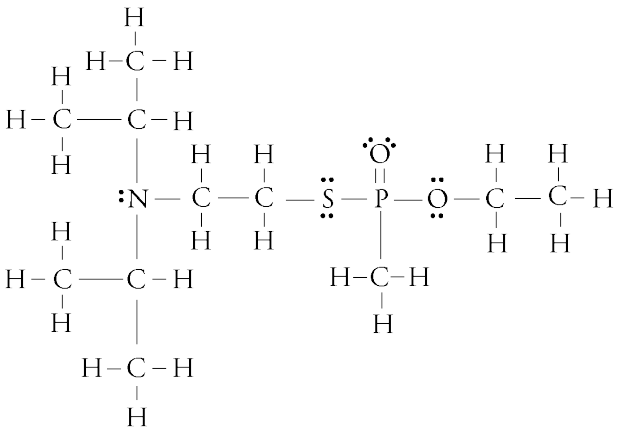
h. It has been suggested that the OPCW step in and evaluate the situation. Describe the steps that the OPCW goes through to determine whether chemical weapons have been used. (4 points)

The following are the general steps, which don't all apply in this situation.

1. **Obtain permission to enter the country, and arrange for safe passage.**
2. **Interview people who were exposed or observed the attack, including video interviews**
3. **Collect biomedical samples (blood and urine)**
4. **Collect environmental samples**
5. **Documenting a clear chain of custody, transfer the samples to a verified OPCW lab where they are analyzed using instruments, such as a gas chromatograph-mass spectrometer (GC/MS)**
6. **Analyze the results and publish the findings.**

i. Draw a Lewis structure that corresponds to the line drawing of VX below.





3. Let's assume that you have been radicalized by ISIL (ISIS), and you are now committed to their cause. Because of your growing knowledge of chemical weapons, you have been asked to provide general information about some of them and make recommendations for their use. Although ISIL does not yet have technical excellence in the areas of making, handling, and dispersal of chemical weapons, your contacts in ISIL tell you that the group now has followers with advanced scientific education in Western universities and Iraqi followers who have WMD experience. They also have access to chemical equipment captured from Mosul University in Iraq, and they have moved much of this equipment to a secure area in Syria where it will be safe from attack in Mosul. They have obtained other basic chemical equipment from captured chemical plants. They also are willing to commit a significant amount of money to making chemical weapons and developing their ability to handle and disperse them.
    a. First they ask you some questions about hydrogen cyanide, HCN.
        i. Draw a Lewis structure for hydrogen cyanide. (3 points)

        $H-C\equiv N:$

        ii. Describe the different ways that ISIL would obtain hydrogen cyanide. How easy do you think it would be? Briefly, explain why. (3 points)

        Because hydrogen cyanide is produced and used in large quantities in the chemical industry, it could be stolen from a chemical facility. It is fairly difficult to make, but the precursors are readily available. Cyanide is transported as solid sodium or potassium cyanide or one of these in solution, so it could be diverted in transport. The sodium or potassium cyanide can be converted into hydrogen cyanide.

iii. Is hydrogen cyanide more likely to be **lethal** or incapacitating? (2 points)

lethal

iv. Which schedule for the CWC is hydrogen cyanide on? Is it on Part A or Part B? Explain why. (4 points)

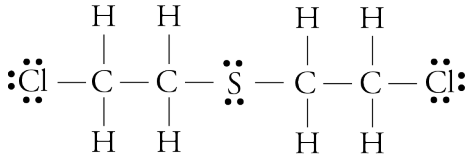
3A, it is a toxic chemical (chemical weapon) that has large-scale legitimate uses.

v. When hydrogen cyanide moves into the bloodstream from the lungs, what physiological changes does it cause? Why are these changes damaging to the body? (3 points)

Cyanide attaches to the cytochrome oxidase enzyme and deactivates it. This disrupt cellular respiration, which involves converting the chemicals from food and oxygen into carbon dioxide, water, and energy. The energy released (and stored in high-energy molecules) is necessary for cell function, so without the energy, the cells die. This leads to a wide-range of ill effects in the body.

b. Next, they ask you some questions about sulfur mustard, $ClCH_2CH_2SCH_2CH_2Cl$.

i. Draw a Lewis structure for sulfur mustard. (3 points)



ii. Is it difficult to obtain the precursors for mustard agent? Explain why or why not? Compared to the difficulty in making nerve agents, how difficult is it to make sulfur mustard if the precursors are available? Briefly, explain why. (3 points)

Thiodiglycol, which has small-scale legitimate uses, is the immediate precursor for mustard agent. It is on Schedule 2, part B of the Chemical Weapons Convention, so its sale and movement is monitored more closely than other chemicals, making it more difficult to obtain. If one could get thiodiglycol, it is much easier to make impure sulfur mustard than to make nerve agents. Sulfur mustard can be made from different precursors that are not listed in the CWC and are more readily available.

iii. Is mustard agent more likely to be lethal or incapacitating? (2 points)

incapacitating

iv. Which schedule for the CWC is sulfur mustard on? Is it on Part A or Part B? Explain why. (4 points)

1A, it is a toxic chemical (chemical weapon) that has no legitimate uses.

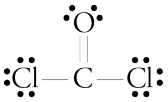
v. How persistent is sulfur mustard on the ground compared to hydrogen cyanide and sarin? Why might its persistence or lack of persistence lead to a tactical advantage? (3 points)

It is fairly stable and not very water soluble, so it is persistent. This makes it an area denial weapon, which requires some decontamination before exposed areas are safe.

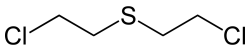
vi. What chemical in human cells is most significantly affected by exposure to sulfur mustard? Why does this effect lead to cell disruption or even cell death? (3 points)

Sulfur mustard is thought to attach to the guanine base on DNA, which disrupts DNA replication and, therefore, cell division. This also leads to changing the information transferred to mRNA and disrupting protein synthesis. Because proteins are essential to the function of cells, damage to cells and cell death occur.

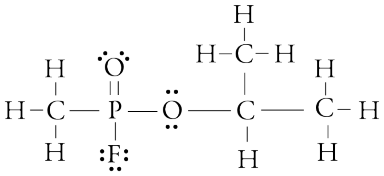
4. Identify each of the following structures as chlorine, phosgene, sulfur mustard, hydrogen cyanide, sarin, VX, fentanyl, BZ, or ricin. (2 point each)

a. 

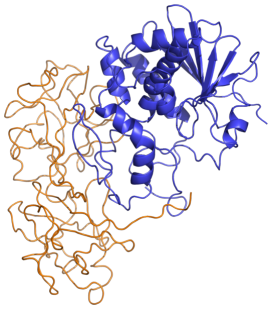
Phosgene

b. 

Sulfur mustard

c. 

Sarin

d. 

Ricin

5. Identify each of the following descriptions as associated with chlorine, phosgene, sulfur mustard, hydrogen cyanide, sarin, VX, fentanyl, BZ, or ricin. (2 points each)

    a. **VX** This chemical agent was first produced in England in 1954. It disrupts the mechanism by which nerves transfer messages to organs, causing seizures and loss of body control. A small drop on the skin could kill an adult in fifteen minutes. When sprayed on the ground, it remains lethal for up to three weeks, so it is an area denial weapon. The U.S. still has some of this agent stored in Bluegrass, Kentucky. It will be destroyed by chemical neutralization.

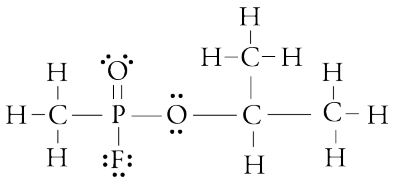
    b. **Chlorine** This gas was the first chemical weapon used by the Germans in the first world war. It reacts with water to form hydrochloric acid and hypochlorous acid, which damage tissues in the lungs and draw water into the lungs causing "dry-land drowning".

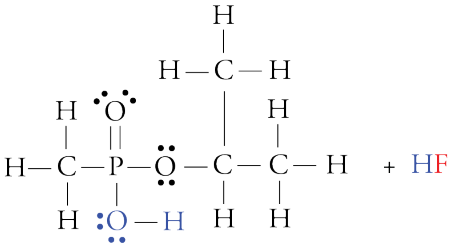
    c. **BZ** This chemical agent is a military incapacitating agent. Its effects are similar to atropine. It is a competitive inhibitor of acetylcholine at receptor sites in smooth muscle, exocrine glands, autonomic ganglia, and the brain. The effects include stupor, confusion, and hallucinations. It is on schedule 2 of the Chemical Weapons Convention.

    d. **Sarin** This chemical agent disrupts the mechanism by which nerves transfer messages to organs, causing seizures and loss of body control. It was adopted as the standard U.S. chemical agent in its general category in 1948.

    e. **Phosgene** This chemical agent causes suffocation by reacting with proteins in the lungs to disrupt the blood-air barrier. It is used to make important compounds, including pharmaceuticals and plastics. It smells like new-mown hay.

6. The Lewis structure for sarin is below. Sketch the Lewis structures for the products of first step in the hydrolysis of sarin. (4 Points)





7. One of the ways to discover whether sarin was used in a chemical attack is to test for the presence of isopropyl methylphosphonic acid (IMPA).
    a. Explain why IMPA is more likely to be found in the attack site than sarin itself. (3 Points)

    IMPA is more stable than sarin, so its hydrolysis is much slower than that for sarin. It is also less volatile than sarin. Because of these factors, it can be found in the environment long after sarin is gone.

    b. Explain why the detection of IMPA is an indication that sarin was present where the IMPA was found. (3 Points)

    IMPA is not found in nature, and sarin is the only substance that forms it, so if IMPA is present, sarin was present.

8. Describe the goals of the Australia Group and describe some of the difficulties in achieving these goals. (4 Points)

   According to the Australia Group website, "*The Australia Group (AG) is an informal forum of countries which, through the harmonisation of export controls, seeks to ensure that exports do not contribute to the development of chemical or biological weapons. Coordination of national export control measures assists Australia Group participants to fulfil their obligations under the Chemical Weapons Convention and the Biological and Toxin Weapons Convention to the fullest extent possible. The principal objective of Australia Group participants' is to use licensing measures to ensure that exports of certain chemicals, biological agents, and dual-use chemical and biological manufacturing facilities and equipment, do not contribute to the spread of CBW. The Group achieves this by harmonising participating countries' national export licensing measures. The Group's activities are especially important given that the international chemical and biotechnology industries are a target for proliferators as a source of materials for CBW programs.*"

   There are 42 member countries, but four of the top-ten chemical-producing countries are not members (Russia, China, India, and Brazil).
   There are a variety of other factors that make it difficult to regulate chemicals, biological agents, and dual-use chemical and biological manufacturing facilities and equipment. Many of these have legitimate uses, so it can be difficult to distinguish between the legitimate uses and uses to make chemical and biological weapons. There are also a huge number of different chemicals and supplies that move from one country to another. Cooperation can lead to extra expenses.