Blood Typing Chemistry

Part of: **Dartmouth Rural STEM Educator Partnership**

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Driving Question **How can we determine the identity of a chemical mixture from a given set of chemical mixtures? (If we know that there are three types of simulated blood, how can we determine to which type an unknown blood sample belongs?)**	**Overview** Students will learn about chemical reactions by experimentally determining the "type" of a mystery simulated blood sample. The simulated reactions are between various A antigens and B antibodies and B antigens and A antibodies. The actual chemical reactions are between 1) aluminum nitrate and sodium salicylate and 2) calcium nitrate and sodium sulfate; both reactions produce a visible precipitate.
NGSS Standards MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function. **CCC's:**MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures. **SEP's:** MS-LS1-1. Conduct an investigation to produce data to serve as the basis for evidence that meet the goals of an investigation.	**Objectives** Through this lesson, students will (2-3 measurable objectives): provide

Materials

An Innovating Science "Simulated ABO/Rh Blood Typing" kit, available from homesciencetools.com or thomassci.com, approximately $50 per kit. 1 kit is sufficient for a classroom of up to 30 (or more?) students.

Preparation

Open kits and distribute small plastic trays and mixing toothpicks; five trays per group?

Background information

Experimental design and sufficient evidence. Potentially ABORh blood typing. Potentially chemical reactions/activation energy/low energy states.

Story line to frame the lesson

Scissors were stolen from the classroom, but in the process the person who stole the scissors cut themselves and left a drop of blood on a desk. Students will need to analyze this drop of blood and determine its ABO type as they collect evidence about who might *not* have stolen the scissors.

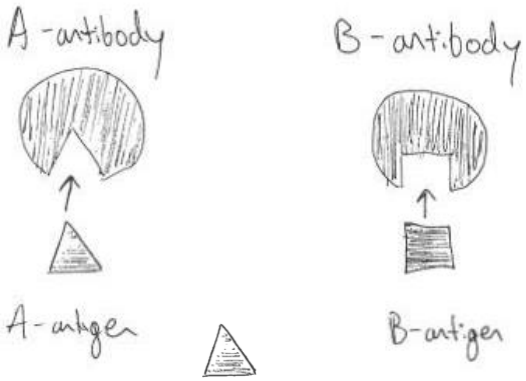
Lesson

Warm Up (5 minutes): What is a chemical reaction? How do we know a chemical reaction has occurred? How are chemical reactions activated?

Mini Lesson (10 - 20 minutes):

Teach the chemistry of ABO blood types by focusing on what types of blood react with other types of blood. (See the kit instructions for a version of this lesson that is less focused on chemical reactions, more focused on the biology. Also note that while ABO blood typing is most common, there are more typing systems, and corresponding antigens and antibodies, than are discussed in this lesson).

Emphasize that A-antigen reacts with an A-antibody and a B-antigen reacts with a B-antibody. Drawing this with shapes is useful. When antigens and antibodies react they cause cells to clump together and "agglutinate." This "agglutination reaction" is similar to a precipitation reaction in that a "solid" precipitates out of a "solution." (You could also discuss the real precipitation reactions that occur in the simulated blood kit).



Then classify types of blood by which antigens are on their cells and which antigens are in their antibodies. A-type blood has A antigens on t B antibodies in the plasma;, B-type blood has B antigens on the cells and A antibodies in the plasma, AB-type blood has both A and B type antigens on the cells and no antibodies in the plasma, and O-type blood has no antigens on t A and B antibodies in the plasma.

Blood Type	Antigen	Antibody
A	A	B
B	B	A
AB	A, B	none

O	none	A, B

Reactions occur when at least one of the donor's antigens match one of the recipient's antibodies. Importantly, reactions are not caused by donor antibodies matching recipient antigens (otherwise O-type blood couldn't be donated to any other blood type). Basically, a small amount of bad plasma is no problem, whereas a small amount of bad blood is a big problem. More specifically, the donor plasma is so diluted by the recipient plasma that it doesn't trigger an immune response whereas the donor blood cells, though diluted by the recipient blood, have significant negative health effects if they agglutinate.[1]

Drawing arrows from the antigen column to the antibody column is helpful to show this, as is constructing a table adding "can receive from" and "can donate to" columns.

Group Work (15 - 20 minutes):

Figure 1. Plus signs (+) indicate where an "aglutination reaction" (really double replacement precipitation reaction) has occurred and the resulting solution is visibly cloudy. The donor samples from left to right

[1] As noted at https://www.ncbi.nlm.nih.gov/books/NBK2265/, "Red blood cell incompatibility may also occur when the patient's RBC antigens are attacked by antibodies from the donor's plasma. This tends to be a minor problem because of the small amount of antibody present in the donated plasma, which is further diluted on transfusion into the recipient's circulation."

are Donor1 (type A+, aluminum nitrate), Donor2 (type B-, calcium nitrate), Donor3 (type AB+, aluminum nitrate and calcium nitrate), Donor4 (O-, water). On the left side of each tray is anti-A serum (sodium salicylate) and anti-B serum (sodium sulfate), on the right is the Rh (sodium salicylate) is on the right.

Students will set up the four different trays, add two drops of the serums to the appropriate well, then add the simulated blood to the appropriate tray and mix. Students will observe the trays and mark the wells in which a reaction has occurred. Students will construct a table of blood types and reactions in order to determine the blood type of each donor. Students will then use a fifth tray to determine the type of the mystery blood, matching the results of the fifth tray to the four known trays.

Share Out (5 minutes): Students compare evidence and share what "type" (chemical solution) the mystery simulated blood sample is and answer the question: “how can we determine the identity of a chemical mixture from a given set of chemical mixtures?”

Extensions

Discuss the chemical reactions that actually occur in the blood typing kit. The two reactions that occur are, using molecular formulas:

- $Al(NO_3)_3 + 3C_7H_5NaO_3 \rightarrow C_{21}H_{15}AlO_9 + 3NaNO_3$
- $Ca(NO_3)_2 + Na_2SO_4 \rightarrow CaSO_4 + Na_2(NO_3)_2$

and using chemical names and indicating if a molecule is insoluble:

- aluminum nitrate and sodium salicylate react to form aluminum salicylate (insoluble) and sodium nitrate
- calcium nitrate and sodium sulfate react to form calcium sulfate (insoluble/slightly soluble) and sodium nitrate

Discuss other blood typing systems based on antigens that are not A, B, or Rh

Questions:

- what is a solution? An ionic solution?
- what precipitates? How can we tell? (from known chemical properties, we can't tell a priori)
- are there other ways to determine the mystery blood type?
- how would our experimental design be different with real blood?
- why are the initial chemicals and the resulting chemicals not hazardous? Why can we safely wash them down the sink? Does this depend on the quantity?
- can you predict which chemicals will react based off the chemical formula? why/why not? (this is a difficult question)
- can you predict which chemicals react based off of the solutions in the bottles?
- what chemical reactions occur? why?
- what chemicals react with what other chemicals? how do you know?
- why does aluminum nitrate not react with sodium sulfate? And why does calcium nitrate not react with sodium salicylate?

- do some reactions require more mixing? What does this suggest about the "activation energy" of the different reactions? Identify the reaction with the higher activation energy.

Glossary of terms

Include a glossary of terms if needed.

Appendices

References or other materials as needed.