Olympic Drug Scandal (IR): Teacher Resource

History:

The Olympics are one of the greatest sports competitions in the world. Athletes fight for the gold, using skill, power and speed. Emotion levels are high, the competition is fierce and people will do anything to win. Sometimes people go too far and this can lead to the use of performance enhancing drugs in many sports competitions. One of the most notorious cases of drug doping in athletics came from the 1976 Olympics, when the East German team won most every competition. When Germany reunited, the athletes sued the government for forcing them to take anabolic steroids and stimulants[1]. During the London 2012 Olympics, the British Olympic Association was calling for tougher sanctions on athletes found using performance enhancing drugs[2,3]. But first, we need to be sure they are taking illegal substances, before anyone's career is ruined!

The illicit drugs found in sport range far and wide: anabolic steroids, which increase muscle mass; stimulants, such as amphetamines; and more recently, proteins used to increase blood cell production, thereby increasing the amount of oxygen supplied to the muscles[4,5]. And there are several drugs that are debated and are monitored from year to year[6]. There are several ways drug tests are performed: blood plasma samples, urine samples, and hair. Spectroscopy is often used to determine what drugs are found in these samples or in unknown substances found in an athlete's possession.

Scenario:

The Olympics are on. Four competitors have been found with unlabelled white pills in their lockers. You have been hired by the Olympics Drug Testing Association to determine what is in each pill and if it is illegal in the competition. The pills have been ground, ready for analysis.

Your goal is to establish the functional groups found in each pill. Using a list of known drug molecules, you can narrow down your choices and use a library of spectra to further identify the compounds in the pills. Then you can decide if any of the pills has the possibility of being illegal in sport.

Method:

1. A few Infrared (IR) spectra of some known samples will be run to get used to the IR machine and make sure that it is working correctly.
    - Use the ATR attachment to run the samples.

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[1] Savalescu, J., B. Foddy and M. Clayton. "Why we should allow performing enhancing drugs in sport."*British Journal of Sports Medicine*, **38**, (2004), 666-670.
[2] Kelso, P. "London 2012 Olympics: British Olympic Association Calls for Stiffer Doping Sanctions." The Telegraph, 11 April 2012.
[3] MacMichael, S. "WADA president to urge re-banning of caffeine". Road.cc, 11 Aug 2010, http://road.cc/content/news/21341-wada-president-urge-reconsideration-lifting-caffeine-ban, Accessed 30 April 2012.
[4] BBC Sport, "Olympic Horses Fail Drug Tests". *BBC Sport*, 21 Aug 2008.
[5] World Anti-Doping Agency. "2012 Monitoring Programme", http://www.wada-ama.org/Documents/World_Anti-doping_Program/WADP-Prohibited-list/2012/WADA_Monitoring_Program_2012_EN.pdf, accessed 30 April 2012.
[6] World Anti-Doping Agency. "2012 Prohibited List", http://www.wada-ama.org/Documents/World_Anti-doping_Program/WADP-Prohibited-list/2012/WADA_Prohibited_List_2012_EN.pdf, accessed 30 April 2012.

- Make sure you are supervised by a demonstrator, since the machine is expensive and fragile.

2. Run the known samples on the IR machine. See if students can match the peaks to the known functional groups.
3. Four unknown pills, one from each competitor, will be provided and an IR spectrum should be obtained for each sample.
   - Using the “Basic Organic Functional Group Reference” table provided in the student manual, interpret your spectra and determine if any important functional groups appear.
   - Determine if the IR spectra of the pills could match any of the compounds on the drug worksheet.
4. Using your IR library provided, determine if any of the spectra of the drug molecules match any of the unknown compounds.
   - If any compounds match any of the drugs on the worksheet, do you think they might be illegal in sport?

Questions:

1. If any compounds match any of the drugs on the worksheet, do you think they might be illegal in sport?
   - Drugs that are illegal in spot on the worksheet are: ephedrine (amphetamine), cocaine (increased awareness, etc), heroin (pain killer), morphine (pain killer), and testosterone (increased muscle mass).
   - Drugs that are monitored and have been illegal in the past are: caffeine (increased awareness and pain killing effects) and pseudoephedrine (similar to ephedrine without the effects, but too similar in structure for early tests).
   - The other drugs are all over the counter common drugs and are not illegal in any quantity in sport.
2. What other methods or instrumental techniques could be used to determine the identity of the pills? Would you trust just the IR results? Why or why not?
   - UV/Vis, NMR, Mass Spec, etc.
   - You should not trust merely one test, ever!
3. Testosterone/Epitestosterone and Ephedrine/Pseudoephedrine are optical isomers. How might you be able to distinguish between them?
   - There are special tests such as circular dichrosims, based off the difference in polarity of optical isomers.
   - Technically the fingerprint region of the optical isomers is different, but only quality spectra and a good matching program would show this.

Materials required:

Known samples:

- Ethanol
- Benzaldehyde
- Aspirin

Unknown samples:

1 – Caffeine pills (doped with more pure caffeine)

2 – Ibuprofen

3 – Paracetamol

4 – Pseudoephedrine (doped with 4-amino-phenol)

5 – Aspirin (if needed)

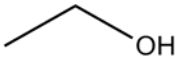
Apparatus required:

- FTIR Infrared spectrometer with ATR attachement
- Tissues for cleaning the machine
- Wash bottle, with isopropanol or ethanol for the ATR
- Pipette for the ethanol and benzaldehyde
- Microspatula
- Disposable Gloves

Paperwork required:

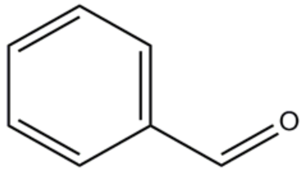
- Drug molecule worksheet
- Unknown pills worksheet
- Background and Method sheets
- Risk assessment and hazard data (need to do this!)
- Evaluation forms.
- Sheet of IR values, either from SIAS resources or an exam board data book

Known compounds worksheet:



ethanol

C=O: 1640-1750cm^{-1}



benzaldehyde

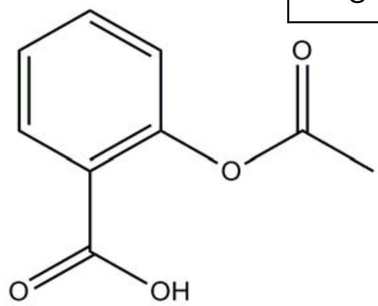
O-H: 3200-3550cm^{-1}

(alc. - broad)

2xC=O: 1640-1750cm^{-1}

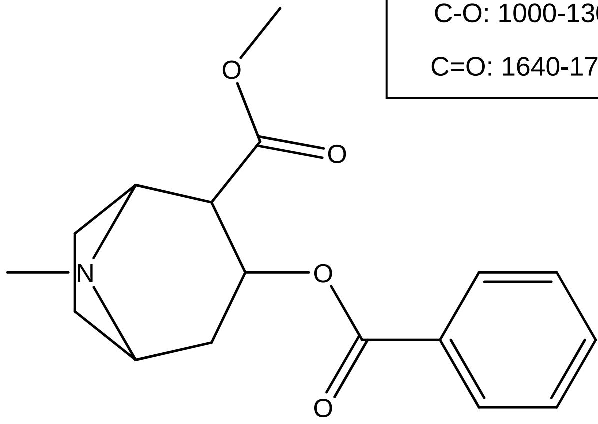
C-O: 1000-1300cm^{-1}

O-H: 2500-3300cm^{-1}



aspirin

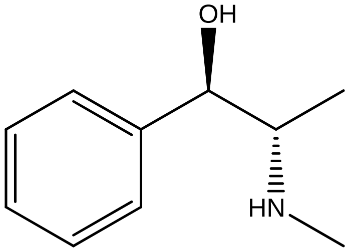
Student worksheet of drug molecules:



C-O: 1000-1300cm^{-1}

C=O: 1640-1750cm^{-1}

cocaine



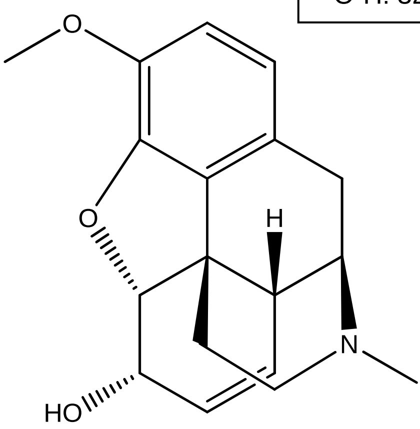
ephedrine

N-H: 3200-3500cm^{-1}

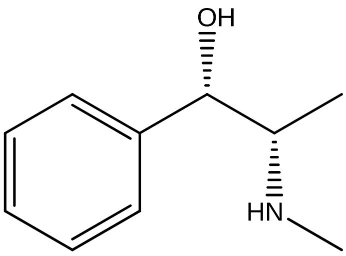
O-H: 3200-3550cm^{-1}

C-O: 1000-1300cm^{-1}

O-H: 3200-3550cm^{-1}



codeine



pseudoephedrine

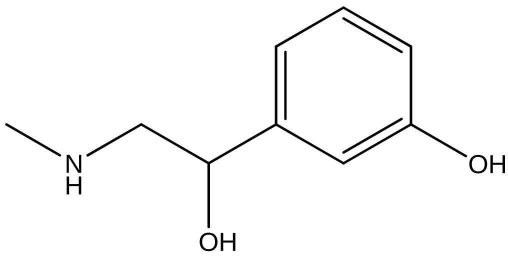
N-H: 3200-3500cm^{-1}

O-H: 3200-3550cm^{-1}

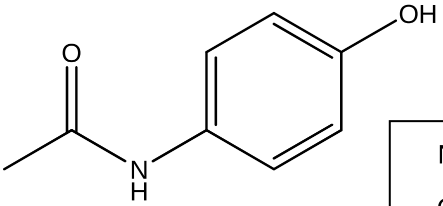
O-H: 3200-3550cm^{-1}

N-H: 3200-3500cm^{-1}

C=O: 1640-1750cm^{-1}



phenylephrine



paracetamol

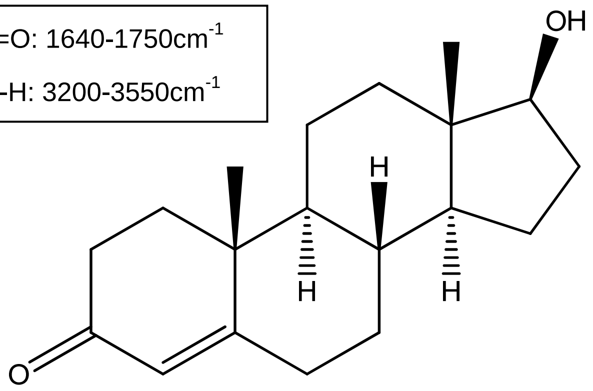
N-H: 3200-3500cm^{-1}

O-H: 3200-3550cm^{-1}

C=O: 1640-1750cm^{-1}

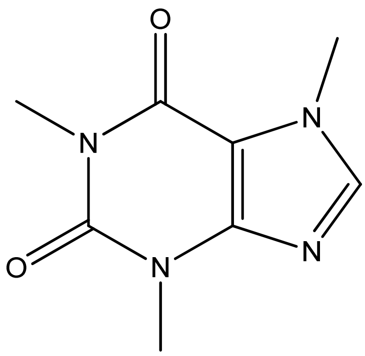
C=O: 1640-1750cm^{-1}

O-H: 3200-3550cm^{-1}



testosterone

2 x C=O: 1640-1750 cm^{-1}

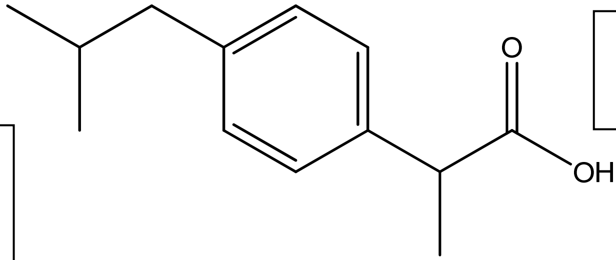


caffeine

N-H: 3200-3500cm^{-1}

O-H: 3200-3550cm^{-1}

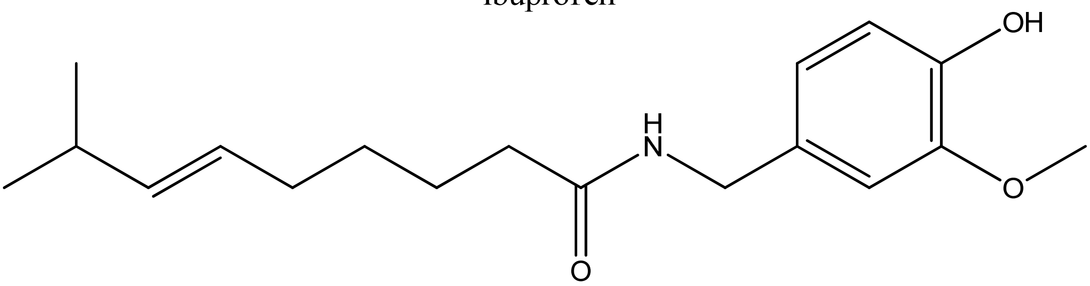
C=O: 1640-1750cm^{-1}



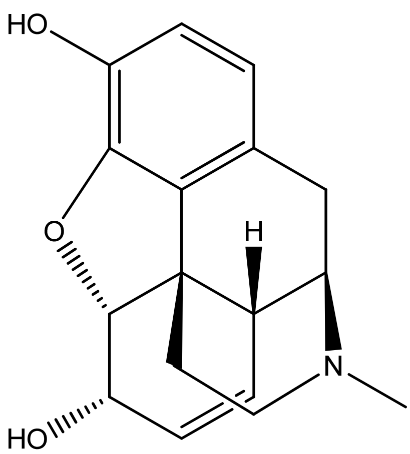
ibuprofen

C=O: 1640-1750cm^{-1}

O-H: 3200-3550cm^{-1}



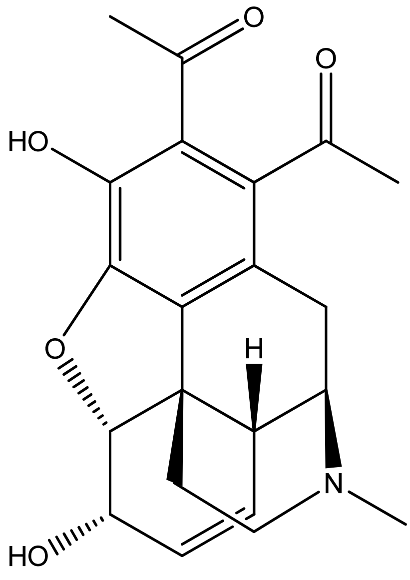
capsaicin



morphine

C-O: 1000-1300cm^{-1}

O-H: 3200-3550cm^{-1}



heroin

O-H: 3200-3550cm^{-1}

C-O: 1000-1300cm^{-1}

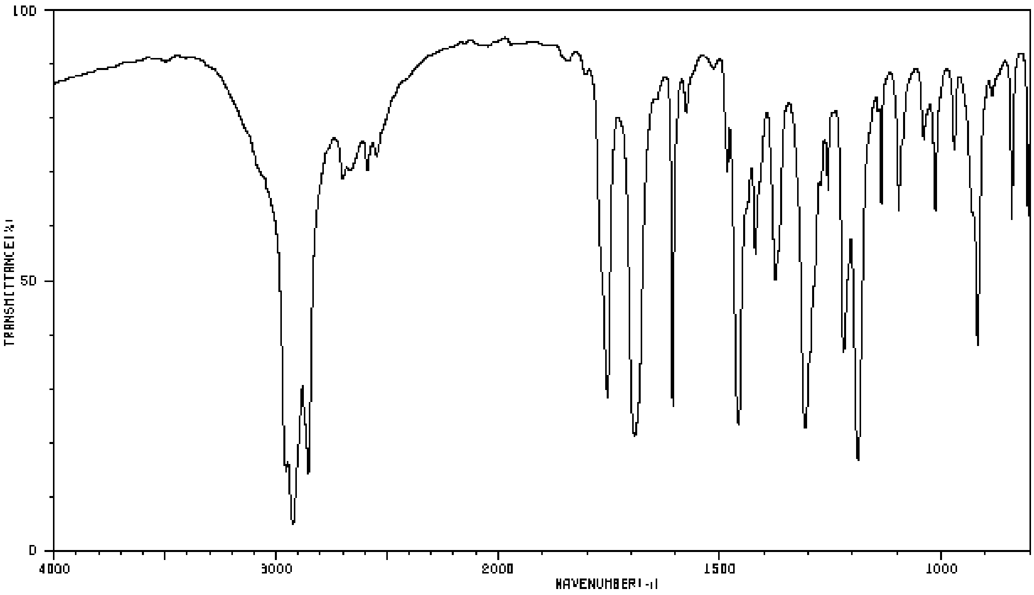
2x C=O: 1640-1750cm^{-1}

Student worksheet:

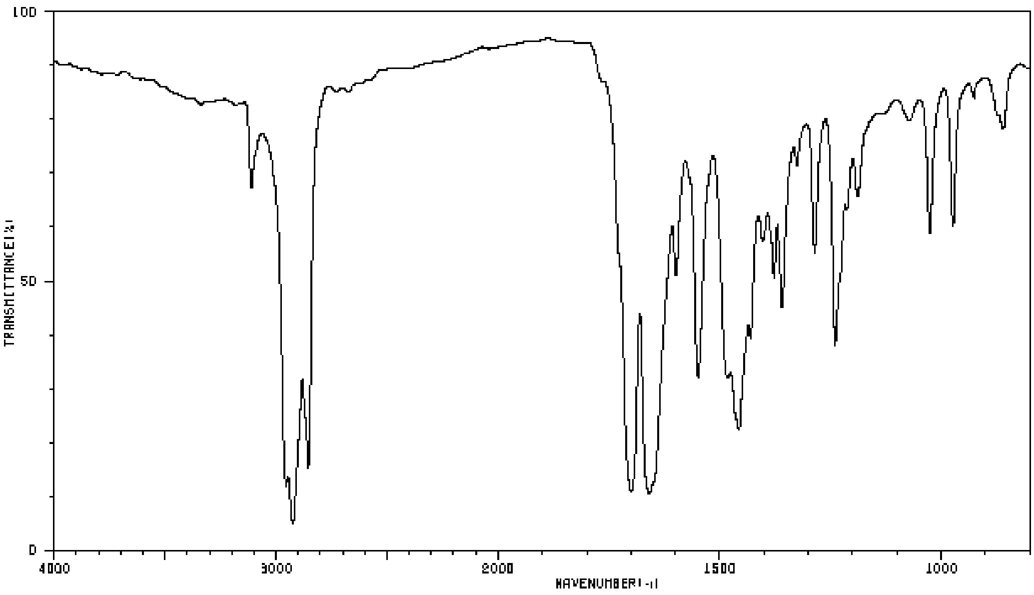
Sample	Functional Group and Range (cm^{-1})	Important Peak Values (cm^{-1})	Name of Chemical (Using Additional Information)
Competitor 1	2 x C=O	1640-1750 cm^{-1}	Caffeine
Competitor 2	C=O O-H	1640-1750cm^{-1} 3200-3550cm^{-1}	Ibuprofen
Competitor 3	O-H N-H C=O	3200-3550cm^{-1} 3200-3500cm^{-1} 1640-1750cm^{-1}	Paracetamol
Competitor 4	N-H O-H	3200-3500cm^{-1} 3200-3550cm^{-1}	Pseudoephedrine/Ephedrine

Infrared spectral library:

Aspirin[7]:

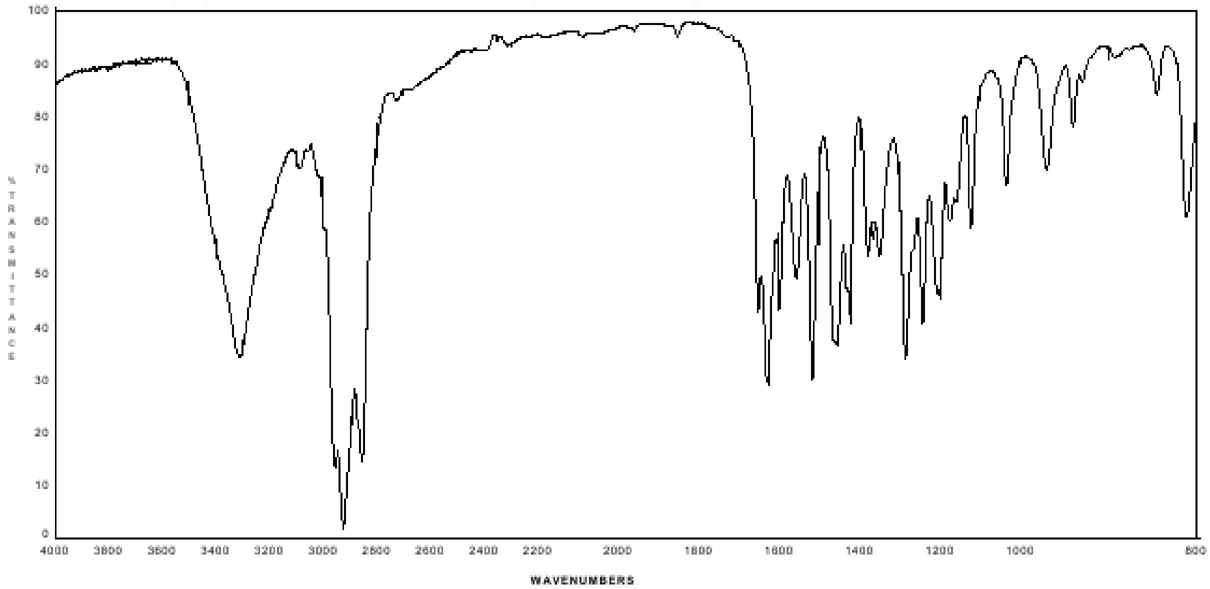


Caffeine[8]:

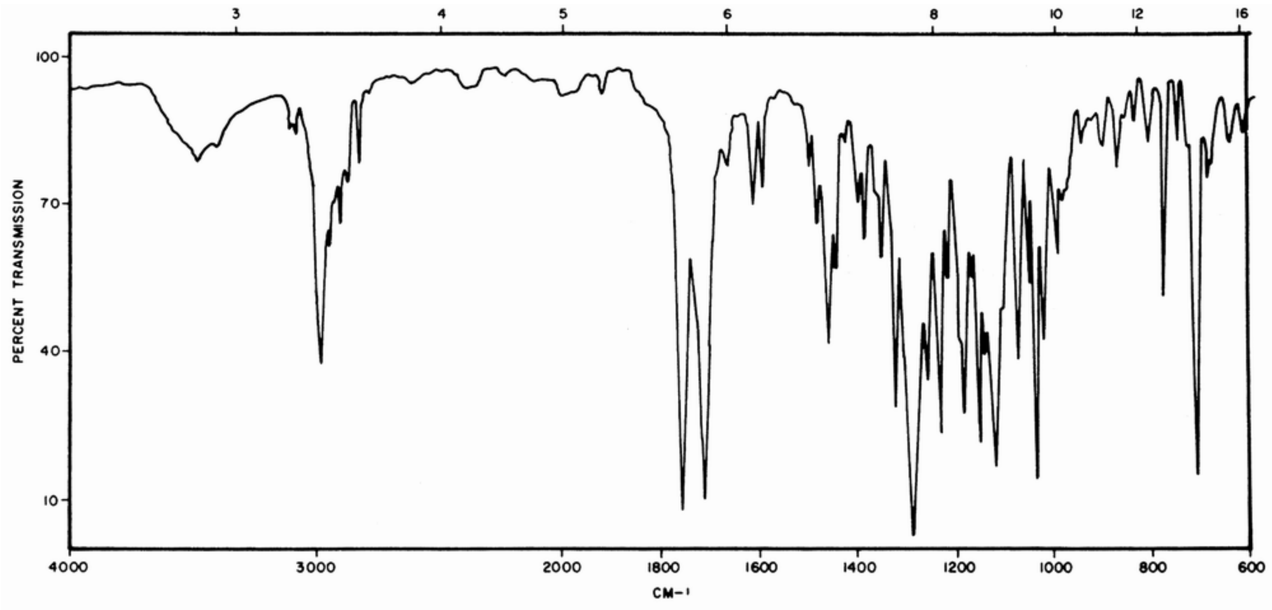


[7,8] Spectra taken from the Spectral Database for Organic Compounds, SDBS. National Institute of Advanced Industrial Science and Technology (AIST), Japan.

Capsaicin[9]:



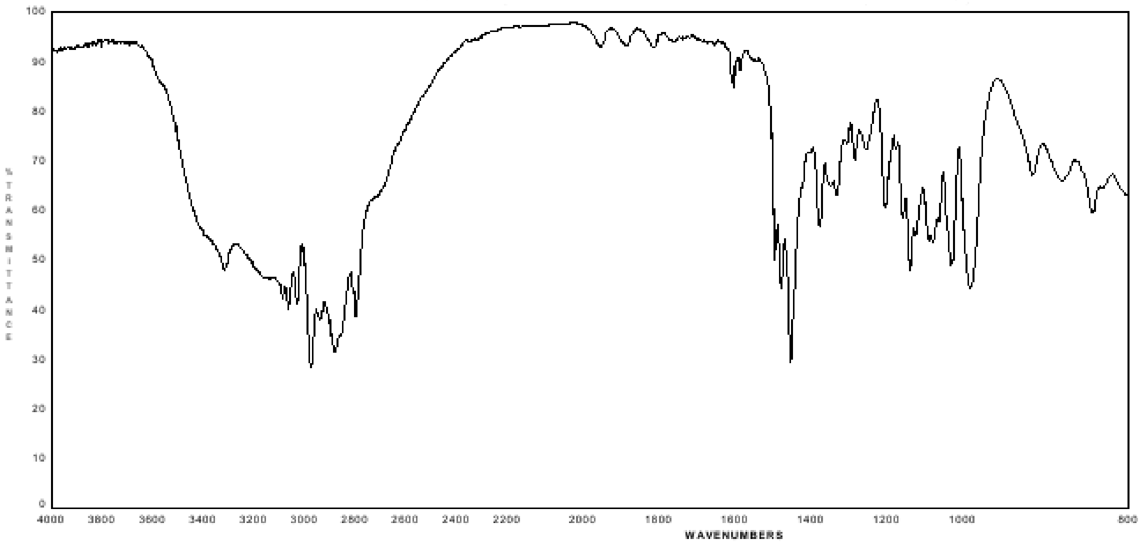
Cocaine[10]:



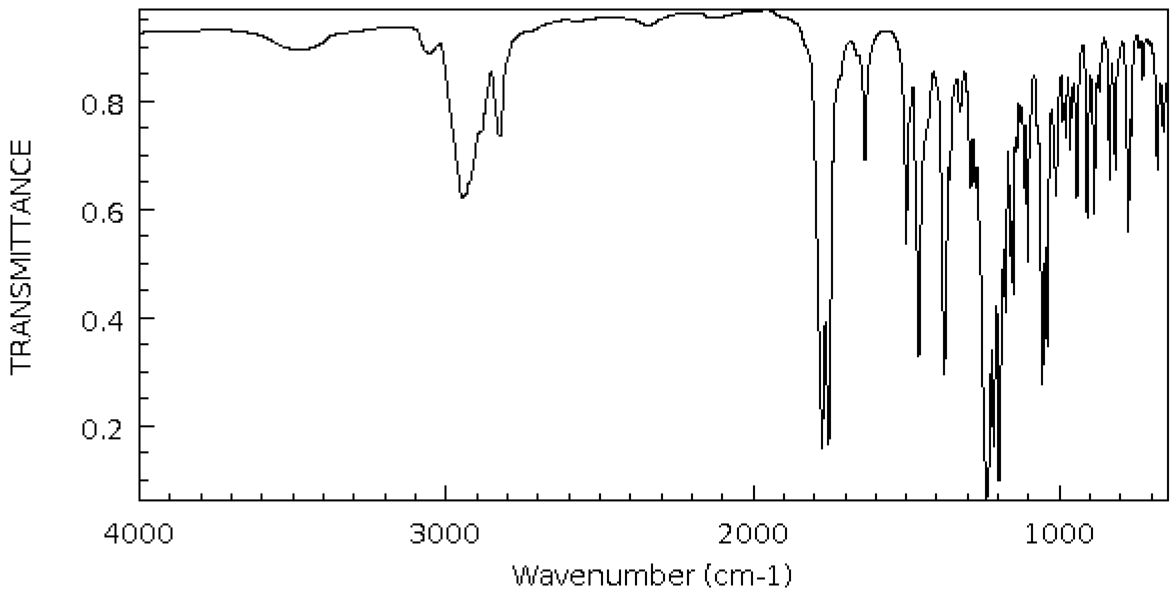
[9] Spectra taken from the Sigma-Aldrich online catalogue (http://www.sigmaaldrich.com/united-kingdom.html, accessed 30 April, 2012)

[10] John F. Casale, "A Practical Total Synthesis of Cocaine's Enantiomers". *Forensic Science International*, **33** (1987) 275-298.

Ephedrine/Pseudoephedrine[11]:



Heroin[12]:



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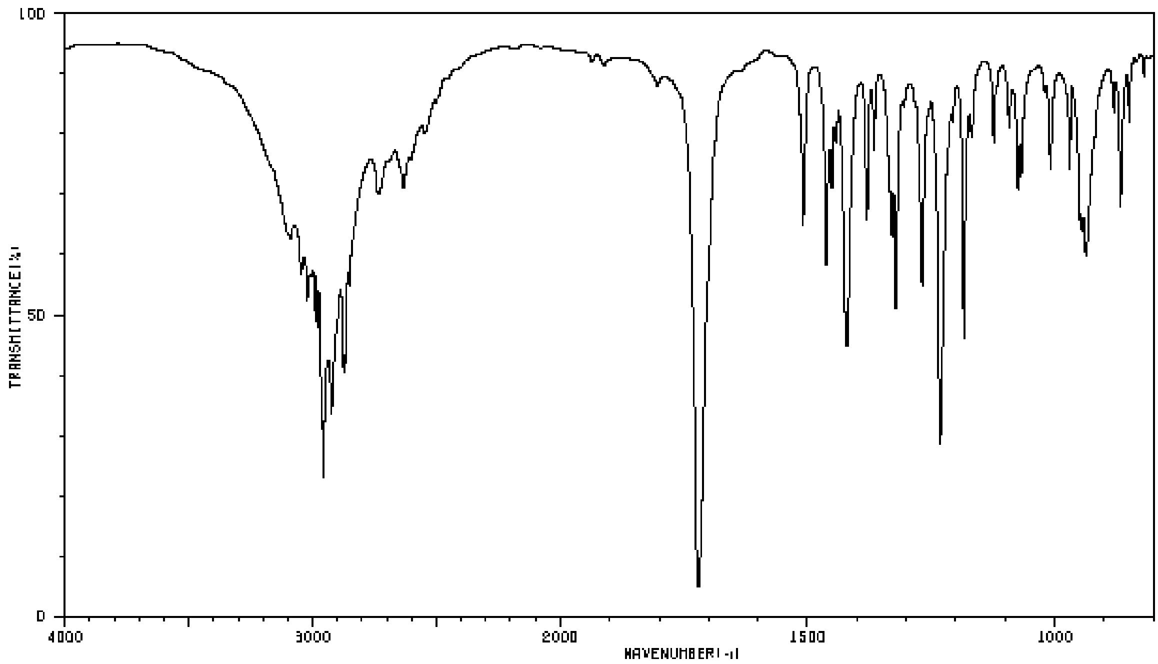
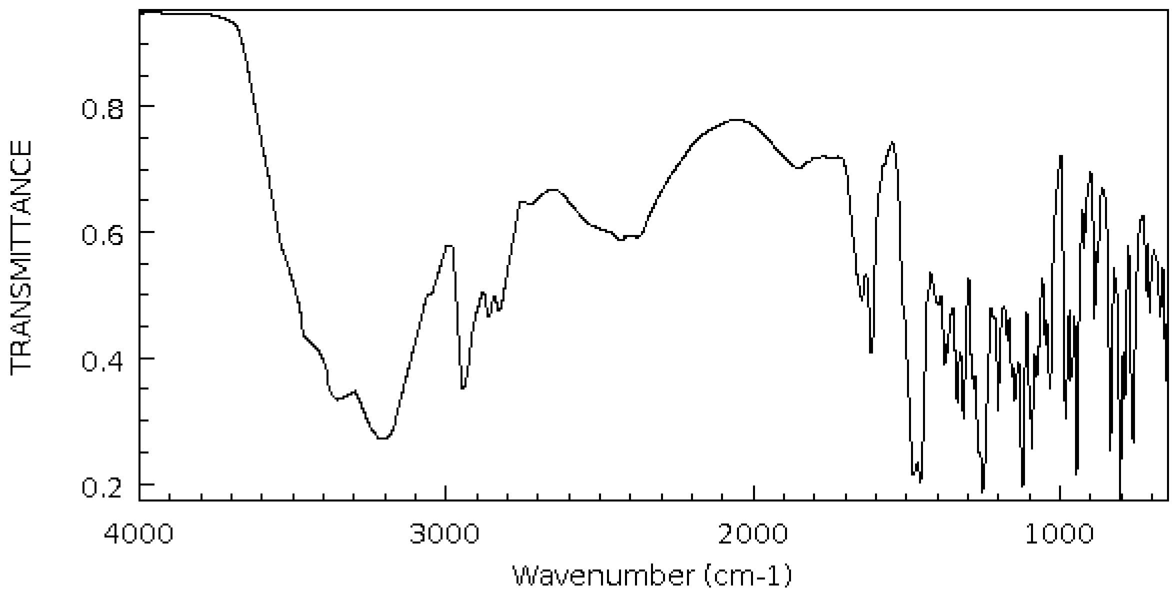
[11] Spectra taken from the Sigma-Aldrich online catalogue (http://www.sigmaaldrich.com/united-kingdom.html, accessed 30 April, 2012)

[12] Spectra taken from the National Institute of Standards and Technology, Chemistry WebBook. (http://webbook.nist.gov/chemistry/, accessed 30 April 2012)

Ibuprofen[13]:



Morphine[14]:



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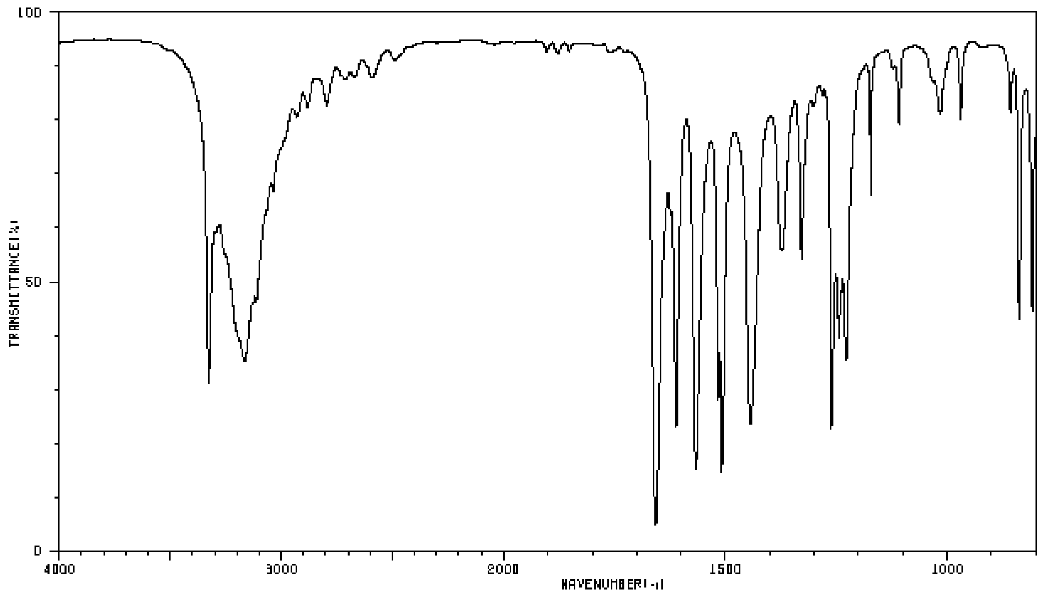
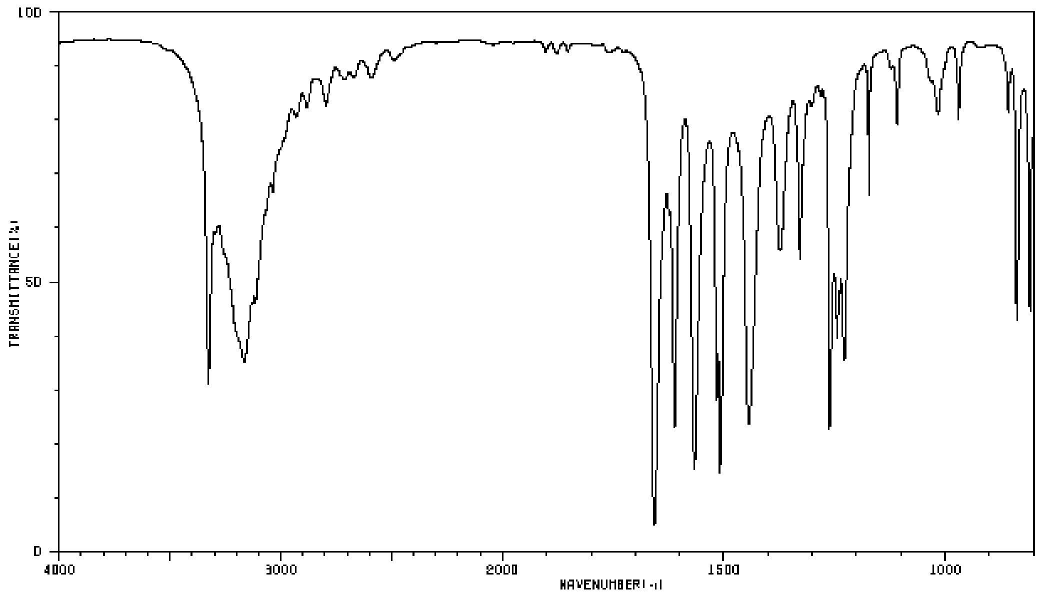
[13] Spectra taken from the Spectral Database for Organic Compounds, SDBS. National Institute of Advanced Industrial Science and Technology (AIST), Japan.
[14] Spectra taken from the National Institute of Standards and Technology, Chemistry WebBook. (http://webbook.nist.gov/chemistry/, accessed 30 April 2012

Paracetamol[15]:

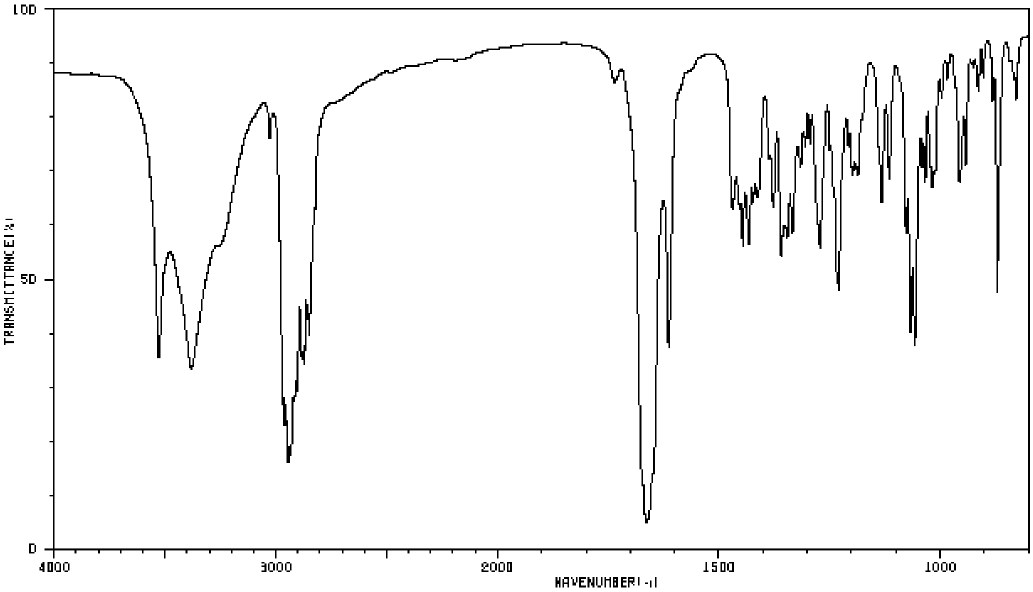


Phenylephrine[16]:



[15,16] Spectra taken from the Spectral Database for Organic Compounds, SDBS. National Institute of Advanced Industrial Science and Technology (AIST), Japan.

Testosterone/Epitestosterone[17]:



[17] Spectra taken from the Spectral Database for Organic Compounds, SDBS. National Institute of Advanced Industrial Science and Technology (AIST), Japan.

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